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A

TREATISE

OF THE

*Animal Oeconomy.*

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BY

BRYAN ROBINSON, M. D.

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DUBLIN,

Printed by GEORGE GRIERSON, for  
C. RIVINGTON, at the *Bible and*  
*Crown* in St. Paul's Church-yard, London.  
M. DCC. XXXII.

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# P R E F A C E.



*I* *N the following Treatise I have avoided Hypotheses, and explained the Laws which obtain in Human Bodies by Reason and Experiments. Hypotheses, of whatever Nature, are not to be admitted in Philosophy. Now whatever is not deduced from the Phænomena, is to be called an Hypothesis.*

*Harvey from Experiments and Observations traced out the Circular Motion of the Blood. After him Lower*  
*a 2 made*

iv P R E F A C E.

*made some farther Discoveries concerning that Motion, and the Causes by which it may be disturbed. After these great Men, the Knowledge of the Animal Oeconomy received no very considerable Improvement, till Sir Isaac Newton discovered the Causes of Muscular Motion, and Secretion ; and likewise furnished Materials for explaining Digestion, Nutrition, and Respiration. To Him I am chiefly indebted for what I have delivered on those Heads.*







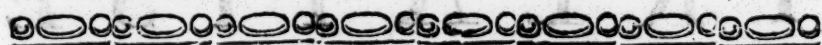
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plain, not by Hypotheses, but by Reason and Experiments. The Parts I shall treat of, are *Muscular Motion, the Motion of the Blood, Respiration, Digestion and Nutrition,*  
A *Secretion,*

*A Treatise of the  
Secretion, and the Discharges of Hu-  
man Bodies.*

In order to explain *the Motion of the Blood*, I shall premise an Account of *the Motion of Fluids thro' Cylindrical Pipes*, and prove the Properties of that Motion by Experiments.



SECTION I.

*Of the Motion of Fluids through Cy-  
lindrical Pipes.*

Proposition I.

**I**F a Fluid be moved through a Cy-  
lindrical Pipe made of a given  
Sort of Matter, by a Force acting con-  
stantly and uniformly during the whole  
Time of the Motion; its Velocity, set-  
ting aside the Resistance of the Air,  
will be in a Ratio compounded of the  
subduplicate Ratio of the moving Force  
directly, and the subduplicate Ratios  
of

*of the Diameter and Length of the Pipe taken together inversely. If F denote the moving Force, D and L the Diameter and Length of the Pipe; I say, that V will be proportional to  $\sqrt{\frac{F}{DL}}$ .*

For the whole Motion of the Fluid flowing thro' the Pipe will, like all other Motions, be measured by the Quantity of Matter moved and its Velocity taken together. But the Quantity of Matter moved is in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith the Fluid flows through the Pipe, and of the Time of the Motion. For the Quantity of Matter or Weight of Fluid contained in the Pipe is opposed to the moving Force during the whole Time of its Action, and must be moved by it for every



indefinitely short Cylinder of Fluid discharged by the Pipe; that is, as often as there are physical Points in the Length of another Cylindrical Pipe of an equal Diameter with that thro' which the Fluid flows, and of such a Length as that it can just contain the Quantity of Fluid discharged in the Time of the Motion; which Length being as the Velocity of the Fluid flowing through the Pipe and the Time of the Motion taken together; the Quantity of Matter moved will be in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith it flows thro' the Pipe, and of the Time of the Motion. And the whole Motion, which is as the Quantity of Matter moved and its Velocity taken together, will be in a Ratio compounded of the simple Ratios of the Quantity

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ty of Matter or Weight of Fluid contained in the Pipe, and of the Time of the Motion; and of the duplicate Ratio of the Velocity: Therefore, putting  $T$  for the Time of the Motion, the whole Motion will be as  $QTV^2$ .

Setting aside the Resistance of the Air, this Motion would be proportional to the moving Force and Time of its acting taken together; that is  $QTV^2$  would be proportional to  $FT$ , if the internal Surface of the Pipe by Friction, or Attraction, or both did not act continually upon the Fluid moving through it, and cause a Change in its Motion proportional to the Efficacy where-with it acts; which Efficacy in a Pipe made of a given Sort of Matter is measured by the Ratio of the internal Surface of the Pipe to the Quantity of Fluid contained in it; that is, by  $DL$  applied to  $Q$ .  
And

And by Consequence  $\frac{QTV^2DL}{Q}$  will be proportional to  $FT$ , and therefore  $V$  will be proportional to  $\sqrt{\frac{F}{DL}}$ ;

*Cor. 1.* If the moving Force and Diameter of the Pipe be both given; the Velocity, setting aside the Resistance of the Air, will be in the inverse subduplicate Ratio of the Length of the Pipe. If  $F$  and  $D$  be given;  $V$  will be as  $\sqrt{\frac{1}{L}}$ .

*Cor. 2.* If the moving Force be as the Quantity of Fluid contained in the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe and Density of the Fluid taken together. Putting  $\Delta$  for the Density of the Fluid, if  $F$  be as  $D^2L\Delta$ ; then  $V$  will be as  $\sqrt{D\Delta}$ .

*Cor.*



ANIMAL OECONOMY. 7

*Cor. 3.* If the moving Force be as the Quantity of Fluid contained in the Pipe, and the Density of the Fluid be given; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If  $F$  be as  $D^2 L \Delta$ , and  $\Delta$  be given; then  $V$  will be as  $\sqrt{D}$ .

*Cor. 4.* If the moving Force be proportional to the Square of the Diameter of the Pipe, and the Length of the Pipe be given; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If  $F$  be as  $D^2$ , and  $L$  be given; then  $V$  will be as  $\sqrt{D}$ .

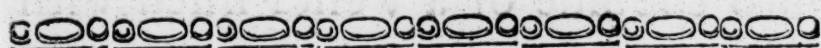
*Cor. 5.* If the moving Force be as the Square of the Diameter of the Pipe; the Velocity, setting aside the Resistance of the Air, will be

be in a Ratio compounded of the subduplicate Ratio of the Diameter of the Pipe directly, and the subduplicate Ratio of its Length inversely. If  $F$  be as  $D^2$ ; then will  $V$  be as  $\sqrt{\frac{D}{L}}$ .

*Cor. 6.* If the moving Force be as the Capacity of the Pipe, if the Diameter of the Pipe be in the subduplicate Ratio of its Length; the Velocity, setting aside the Resistance of the Air, will be in the subquadruplicate Ratio of the Length of the Pipe. If  $F$  be as  $D^2L$ , and  $D$  be as  $\sqrt{L}$ ; then will  $V$  be as  $L^{\frac{1}{4}}$ .

*Cor. 7.* The moving Force, setting aside the Resistance of the Air, will be in a Ratio compounded of the duplicate Ratio of the Velocity, and of the simple Ratios of the Diameter and Length of the Pipe.  $F$  will be as  $V^2DL$ .

*Proof*



*Proof by Experiments.*

TO prove the Truth of this Proposition by Experiments, I procured several Cylindrical Pipes of Brass of different Diameters and Lengths, each of which Pipes had one End fitted to screw into the Side of a Vessel filled with Water at three different Distances from its Top, namely at the Distances of one Foot, two Feet, and four Feet. The Vessel made for these Experiments was a square Wooden Vessel something above four Feet in Depth, and nine Inches of a *London* Foot in its internal Length and Breadth.

Before I give an Account of the Experiments, it will be necessary to shew how to measure the moving Forces and Velocities of Water flowing thro' Cylindrical Pipes screwed

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into



into the Side of a Vessel filled with Water.

To measure the moving Force of Water flowing through a Cylindrical Pipe screw'd into the Side of a Vessel filled with Water, we must know the Area of the Top of the Water in the Vessel, the Area of the Orifice of the Pipe, the perpendicular Distance of the Place of the Pipe's Insertion into the Side of the Vessel from the Top of the Water, and the Situation of the Pipe with respect to the Horizon.

Let the Area of the Top or upper Surface of the Water in the Vessel be called  $A$ , the Area of a Hole made in the Bottom or Side of the Vessel be called  $a$ , and the perpendicular Distance of the Place of Insertion of the Pipe from the Top of the Water be called  $H$ ; and then, by *prop. 36. lib. 2. Princip. Newton.*, the Velocity of the Water flowing out  
of

of the Hole, setting aside the Resistance of the Air, will be equal to the Velocity which a heavy Body would acquire in falling perpendicularly and without Resistance thro' the Space  $\frac{A^2 H}{A^2 - a^2}$ . And, by the second *Corollary* of the same *Proposition*, the Force generating the whole Motion of the effluent Water will be equal to the Weight of a Cylinder of Water whose Base is  $\frac{12}{17}$  parts of the Area of the Hole or  $a$ , and whose Height is  $\frac{2 A^2 H}{A^2 - a^2}$ . If the Area of the Hole be exceedingly small when compared with the Area of the upper Surface of the Water; that is, if  $a$  be exceeding small when compared with  $A$ ; the Height  $\frac{2 A^2 H}{A^2 - a^2}$  will be very nearly equal to  $2H$ ; and by Consequence the Force generating the whole Motion of the effluent Water will be very nearly equal to

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the

the Weight of a Cylinder of Water whose Base is  $\frac{13}{17}a$ , and whose Height is  $2H$ ; that is very nearly equal to the Weight of the Cylinder  $\frac{24}{17}aH$ : But the Weight of this Cylinder is proportional to the Weight of the Cylinder  $aH$ , because  $\frac{24}{17}$  is an invariable Quantity: And therefore when the Area of the Hole is extremely small in comparison of the Area of the Top of the Water, the Force generating the whole Motion of the effluent Water will be very nearly proportional to the Weight of the Cylinder  $aH$ .

The Force generating the Motion of Water flowing thro' a Cylindrical Pipe screw'd into the Side of a Vessel fill'd with Water, and laid parallel to the Horizon, is something greater than the Force generating the Motion of Water flowing through a Hole of a Diameter equal to that of the Pipe, and which  
is



is placed at an equal Distance from the Top of the Water ; as will appear by considering the Nature of these two Motions.

In observing the Motion of Water flowing through a Hole made in the Side of a Vessel, we may perceive the Vein not to fill the Hole. Sir *Isaac Newton*, in determining this Motion from Experiments, found the Vein, after it had passed out of the Hole, to grow smaller and smaller, till it came to a Distance very nearly equal to the Diameter of the Hole ; at which place he measured the Diameter of the Vein, and found it to be to the Diameter of the Hole, as 21 to 25. The Area of a transverse Section of the Vein at that Distance from the Hole, is to the Area of the Hole ; as the Square of the Diameter of the Vein, to the Square of the Diameter of the Hole ; that is, as 12 is to 17 nearly. This  
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Contraction of the Vein arises from the Nature of the Motion of the Water down the Vessel: For the Water falls down from the Top of the Vessel to the Hole not perpendicularly but obliquely, its Parts moving laterally as well as downwards. By this oblique Motion it is, that the Column of the descending Water grows narrower perpetually from the Top of the Water to the Hole, and to a small Distance beyond it; and that the Vein does not fill the Hole, but falls within it, leaving a little empty Space all round. On account of this Contraction of the Vein less Water flows out, and by Consequence less Motion is generated in a given Time, than would be produced, if the Diameter of the Vein at the Hole was exactly equal to the Diameter of the Hole. And as less Motion is generated, so the moving Force is likewise less; being  
only

only equal to the Weight of a Cylinder of Water whose Magnitude is  $\frac{24}{17}aH$ , when the Hole is extremely small in comparison of the upper Surface of the Water; whereas it would be equal to the Weight of a Cylinder of Water whose Magnitude is  $2aH$ , if the Vein filled the Hole and had no Contraction beyond it. And therefore the moving Force is less than it would be if the Vein filled the Hole and had no Contraction beyond it, in the Proportion of 12 to 17.

If instead of flowing through the Hole into the open Air, the Water flows through the Hole into a Cylindrical Pipe and through that into the Air, and if the Diameter of the Hole be equal to that of the Pipe; the Force generating the Motion of the Water flowing through the Pipe will be different from the  
Force



Force generating the Motion of the Water flowing through the Hole.

First, let us suppose the Pipe to lie parallel to the Horizon; and then the Force generating the Motion of the Water flowing through it will be greater than the Force generating the Motion of the Water flowing through the Hole. For the Weight of Water in the Pipe, and the Resistance arising from the internal Surface of the Pipe, do both of them, by acting in a kind of Opposition to the Weight of the descending Cataract in the Vessel, retard the Motion of the Cataract, and hinder it from flowing so fast into the Pipe, as it does through the Hole into the open Air. And by this Opposition they make the Base of the Cataract at its Entrance into the Pipe to spread and grow broader, and by Consequence encrease the moving Force, and  
make

make it greater than the Force generating the Motion of the Water flowing through the Hole. Hence it is evident, that the moving Force will encrease, either on encreasing the Length of the Pipe or lessening its Diameter; and will be greatest, when the Pipe is infinitely long or infinitely narrow: In which Cases the Base of the Cataract at its Entrance into the Pipe will exactly fill it, and the moving Force will be equal to the Weight of the Cylinder of Water  $2aH$ ; and by Consequence will be greater than the Force generating the Motion of the Water flowing through the Hole, in the Proportion of 12 to 17, and the Motion generated in the Water flowing thro' the Pipe will be greater than the Motion generated in the Water flowing thro' the Hole; and the Difference of these two Motions will be greater when the Pipe

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is long or narrow, than when it is short or wide. And therefore, if we suppose the Forces generating the Motions of Water flowing through Cylindrical Pipes laid parallel to the Horizon, to be equal to the Forces generating the Motions of Water flowing through Holes of equal Diameters, and placed at equal perpendicular Distances from the upper Surface of the Water in the Vessel, on which Supposition the Force generating the Motion of Water flowing through a Pipe will be proportional to the Weight of a Cylinder of Water whose Magnitude is  $aH$ , the Motion of the Water flowing thro' a longer or a narrower Pipe, when compared with the Motion of the Water flowing thro' a shorter or a wider Pipe, will be found by Experiments to be something greater than it ought to be on this Supposition of the moving Force.

But



But the Difference will be but small in Pipes of small Lengths and Diameters, and therefore in the following Experiments, when a Pipe lies horizontally, I shall suppose the moving Force to be proportional to the Weight of the Cylinder aH.

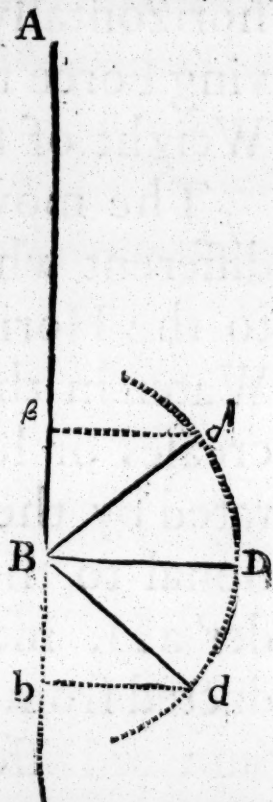
The moving Force will become different when the Pipe is inclined to the Horizon. The Weight of Water in the Pipe, as far as it increases or lessens the Motion generated by the Force which is proportional to the Weight of the Cylinder aH, must be added to or subducted from that Weight; and the Sum or Difference will be proportional to the Force generating the Motion of the Water flowing thro' the Pipe in that inclined Position. The part of the Weight of the Water in the Pipe which is to be added to or subducted from the Weight of the Cylinder aH may be

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thus

thus determined. Let BD be a Cylindrical Pipe, lying parallel to the Horizon, with its End B inserted into the Side of the Vessel at the perpendicular Distance of BA from the Top of the Water; the Force generating the Motion of the Water flowing thro' this Pipe, is proportional to the Weight of the Cylinder  $a \times AB$ , because in this Case H is equal to AB. Let the Pipe be turned from its horizontal Position, either downwards into the Position Bd, or upwards into the Position B $\alpha$ ; and then the moving Force will be changed, and be proportional to the Weight of the Cylinder  $a \times Ab$  in the first Case, and to the Weight of the Cylinder  $a \times A\beta$  in the second. For the



the Weight of the Water in the Pipe Bd encreaseth the Motion of the Water flowing through it, and the part of this Weight which is wholly spent in encreasing the Motion, is, from the Laws of Motion of Bodies down inclined Planes, the  $\frac{Bb}{Bd}$  part of the Weight of Water contained in the Pipe, or of the Cylinder  $a \times Bd$ ; and therefore is equal to the Weight of the Cylinder  $a \times Bb$ . This Weight added to the Weight of the Cylinder  $a \times AB$  gives the Weight of the Cylinder  $a \times Ab$ , which Weight is the Force generating the Motion of the Water flowing thro' the Pipe Bd. The Weight of Water in the Pipe  $B\beta$  lessens the Motion of the Water flowing thro' it, and the part of the Weight which is wholly spent in lessening the Motion, is the Weight of the Cylinder  $a \times B\beta$ . This Weight subducted from the



the Weight of the Cylinder  $a \times AB$ , leaves the Weight of the Cylinder  $a \times A\beta$ , which Weight is the Force generating the Motion of the Water flowing through the Pipe  $B\lambda$ .

If  $B$  be made the Center of a Circle, and  $Bd$  or  $B\delta$  the Radius,  $Bb$  will be the right Sine of  $Bdb$  the Angle of Depression of the Pipe below the Plane of the Horizon, and  $B\beta$  will be the right Sine of  $B\delta\beta$  the Angle of its Elevation above it. And by Consequence, when the Pipe is depressed below the Horizon; the moving Force will be proportional to the Weight of a Cylinder of Water, of a Base equal to the Orifice of the Pipe, and of a Height equal to the Sum of the perpendicular Height of the Water in the Vessel above the Place where the Pipe is inserted and the right Sine of the Angle of Depression of the Pipe below the Plane of the Horizon: And when the Pipe  
is

is elevated above the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whose Base is equal to the Orifice of the Pipe, and whose Height is equal to the Difference of the perpendicular Height of the Water in the Vessel above the Place of Insertion and the right Sine of the Angle of Elevation of the Pipe above the Plane of the Horizon. If  $S$  denote the right Sine of the Angle in which the Pipe is depressed below or elevated above the Plane of the Horizon, the moving Force will be proportional to the Weight of the Cylinder  $a \times \overline{H + S}$  when the Pipe is depressed below the Horizon, and proportional to the Weight of the Cylinder  $a \times \overline{H - S}$  when it is elevated above it; and comprehending both Cases in one Expression, the moving Force will be as  $a \times \overline{H \pm S}$ , or as  $D^2 \times \overline{H \pm S}$ , very nearly.

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To measure the Velocity of Water flowing through a Cylindrical Pipe screw'd into the Side of a Vessel filled with Water.  $V$  by this *Proposition* is as  $\sqrt{\frac{F}{DL}}$ ; or as  $\sqrt{\frac{D^2 \times H \pm S}{DL}}$ , or as  $\sqrt{\frac{D \times H \pm S}{L}}$ .

And therefore  $\sqrt{\frac{D \times H \pm S}{L}}$  will be

one Measure of the Velocity. Another Measure of it may be had from Experiments. For the Velocity of Water flowing through a Cylindrical Pipe, lying either parallel or inclined to the Horizon, is proportional to the Quantity of Water discharged in a given Time apply'd to the Orifice of the Pipe. For the Quantity discharged in a given Time apply'd to the Orifice of the Pipe, will give the Length of a Cylindrical Pipe which can just contain that Quantity; which Length is



is the Space that would be described in the Time of the Motion by an uniform Velocity, equal to the Velocity wherewith the Fluid flows through the Pipe when the moving Force acts constantly and uniformly, as it will do if the Vessel be kept constantly full by pouring in Water very gently at the Top as fast as it runs out of the Pipe. But the Velocities of all uniform Motions are as the Spaces described in a given Time; and by Consequence, the uniform Velocity wherewith the Length of the said Cylinder would be described in the given Time of the Motion, will be proportional to that Length; and therefore proportional to the Quantity of Fluid discharged apply'd to the Orifice of the Pipe. Let  $M$  denote the Quantity of Water discharged in the given Time of the Motion; and then the Velocity  $V$  will be proportional

$D$ 
tional

tional to, and consequently measured by  $\frac{M}{a}$ ; or  $\frac{M}{D^2}$ , because Circles are to one another as the Squares of their Diameters.

If the Velocity be rightly measured by this *Proposition*; then  $\sqrt{\frac{D \times H \pm S}{L}}$

must be proportional to  $\frac{M}{D^2}$  very nearly, as it will appear to be by the following Experiments, setting aside the Resistance of the Air.

Tho' in this *Proposition* I have set aside the Resistance given by the Air to this Motion, yet it will be necessary to consider it, in order rightly to understand the Disturbances in the Motion caused by it. Water in flowing out of a Pipe into the open Air communicates a Motion to the Air, and loses so much of its own Motion as it communicates. Now if we suppose the Motion

tion communicated to be proportional to the Square of the Diameter of the Vein of the effluent Water and the Square of its Velocity, taken together; then the Motion communicated to the Air, with respect to the Motion which in the same time would be generated in the Water if the Air gave no Resistance, will be reciprocally as the Length of the Pipe. And by Consequence, in Pipes of the same Length, the Motions communicated to the Air, will on this Supposition be proportional to the Motions of the Water which would be generated if there was no Air, but the Water flow'd out of the Pipes into an empty Space perfectly void of all Matter. And therefore the Resistance of the Air will cause no Disturbance in the Proportions of the Motions of the Water flowing through such Pipes. This Suppo-

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sition,



sition, that the Veins of the effluent Water are resisted by the Air in Proportion to the Squares of their Diameters and the Squares of their Velocities taken together, will not appear unreasonable, when we consider that solid Globes in moving through the Air, are resisted in that Proportion.

*Experiment 1.* Three Cylindrical Pipes, whose Lengths were two, four, and eight Feet, and whose common Diameter was  $\frac{345}{1000}$  parts of an Inch, were one after another screwed into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were laid parallel to the Horizon. These three Pipes thus situated, discharged 175, 133, and  $97\frac{1}{2}$  Troy Ounces of Water in half a Minute. The Pipes having equal Diameters, the Velocities of the Water flowing through them were

as

as the Quantities of Water discharged in equal Times; that is, as the Numbers 175, 133, and  $97\frac{1}{2}$ : For when D is given, V is as M. By the other Measure of the Velocity deduced from this *Proposition*, the Velocities ought to have been reciprocally as the Square Roots of the Lengths of the Pipes; that is, nearly as the Numbers 20000, 14142, and 10000. For the Pipes having equal Diameters, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and all laid parallel to the Horizon; D and H were given, and S was 0; and consequently the Velocity, which by this *Proposition* is as  $\sqrt{\frac{D \times H \pm S}{L}}$ , ought in the present Case to have been as  $\frac{1}{\sqrt{L}}$ . The Velocities from this Measure are nearly proportional

onal to those from Experiments. Those from Experiments with respect to these, are as the Numbers 175, 188, 195 : whence it appears, that the Velocity from Experiment, with respect to the Velocity expressed by the other Measure, is something greater in the longer of any two of these Pipes than in the shorter ; as it ought to be, from what has been said, both on account of the Resistance of the Air, and the Nature of the moving Force.

*Experiment 2.* Three Cylindrical Pipes of equal Lengths, whose Diameters were  $\frac{372}{1000}$ ,  $\frac{185}{1000}$ , and  $\frac{90}{1000}$  parts of an Inch, were one after another screw'd into the Side of the Vessel, at the perpendicular Distance of four Feet from the Top of the Water, and were laid parallel to the Horizon. These Pipes thus situated discharged 179,  $33\frac{1}{2}$ , and  $6\frac{1}{8}$  Ounces of Water in half a Minute. The  
Velo-



Velocities, found by dividing these Quantities by the Squares of the Diameters of their respective Pipes, were as the Numbers 1293, 1008, and 756. By the other Measure they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 193, 136, and 94. For the Pipes having equal Lengths, being all inserted into the Side of the Vessel, at the same perpendicular Distance from the Top of the Water, and being laid parallel to the Horizon;  $L$  and  $H$  were given, and  $S$  was 0; and consequently  $\sqrt{\frac{D \times H + S}{L}}$  was in this Case as  $\sqrt{D}$ . The Velocities from this Measure are nearly proportional to those from Experiments. Those from Experiments, with respect to these, are as the Numbers 670, 741, 804; whence it appears, that the Velocity from  
Expe-

Experiment, with respect to what it ought to be by the Measure of this *Proposition*, is something greater in the narrower of any two of these Pipes than in the wider; as I have shewn it ought to be, from the Nature of the moving Force.

*Experiment 3.* Two Cylindrical Pipes, whose Lengths were eight Feet and two Feet, and whose Diameters were  $\frac{345}{1000}$  and  $\frac{185}{1000}$  parts of an Inch, were screw'd into the Side of the Vessel at the perpendicular Distances of four Feet, and one Foot from the Top of the Water, and were laid parallel to the Horizon. These Pipes thus fixed discharged  $87\frac{1}{2}$ , and 16 Ounces of Water in half a Minute. The Velocities in them, found by dividing their Discharges by the Squares of their Diameters, were nearly as the Numbers 73, and 46. By the other Measure of the Velocity they ought to have been  
as

as the Square Root of the Diameters of the Pipes; that is, nearly as the Numbers 186 and 134: For H and L were each of them 4 in the first Experiment, and 1 in the second, and S was nothing in both; and consequently the Velocity expressed by  $\sqrt{\frac{D \times H \pm S}{L}}$ , in the present Case, was as  $\sqrt{D}$ . The Velocity in the Pipe which was nearer to the Top of the Vessel, was less than it ought to have been by this Measure, in the Proportion of 34 to 39. And in all the Experiments I have made upon this Occasion, I have always found the Velocities in the same Pipes placed at different Distances from the Top of the Water, to be less at less Distances from the Surface than at greater with respect to what they ought to have been by this *Proposition*. This

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may be owing, partly to a Disturbance given to the Motion by the Water which was poured in at the Top of the Vessel in order to keep it constantly full; which Disturbance being greater at a less Distance from the Surface, might cause a greater Loss of Motion: and partly to the moving Force's being in reality something greater at a greater Distance from the Top of the Water, than it ought to be by the Measure I have given of it.

*Experiment 4.* Two Cylindrical Pipes of equal Diameters, and of the Lengths 1 and 4, were one after the other screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were each of them depressed in an Angle of 30 Degrees below the Plane of the Horizon. These Pipes thus situated discharged  $41\frac{3}{8}$  and  $25\frac{3}{8}$  Ounces of  
Water

Water in half a Minute. The Velocities in these Pipes, on account of their having equal Diameters, were as the Quantities discharged. By the other Measure they ought to have been as the Numbers 300 and 173; for D was given because the Pipes had equal Diameters, and being both depressed below the Horizon; the Measure of the Velocity  $\sqrt{\frac{D \times H + S}{L}}$  in this Case

became  $\sqrt{\frac{H + S}{L}}$ . The natural Sine of 30 Degrees being equal to half the Radius, S was half a Foot for the shorter Pipe, and two Feet for the longer; and  $H + S$  was  $4\frac{1}{2}$  for the first, and  $\frac{6}{4}$  or  $\frac{3}{2}$  for the second; or 9 for the first, and 3 for the second. But the Square Roots of 9 and 3 are as the Numbers 300 and 173, which Numbers are nearly in the same Proportion as the Numbers

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41 $\frac{3}{4}$

$41\frac{3}{8}$ , and  $25\frac{3}{8}$ ; and therefore the Velocities were nearly in the same Proportion as they ought to have been by this *Proposition*.

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Proposition II.

**I**F a Fluid flow thro' two Systems of Cylindrical Pipes made of a given Sort of Matter, and consisting each of one Trunk, and the same Number of Branches arising from it; if the Pipes of the two Systems have like Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be as the Capacities of the whole Systems; And if the Forces generating the Motions in two corresponding Pipes be in the same Proportion as the whole moving Forces of the two Systems: The Velocities in the two corresponding Pipes, setting aside the Resistance of  
the



*the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversly. If  $V, v$  be put for the Velocities in the two Pipes;  $D, d$ , and  $L, l$  for their Diameters and Lengths; and  $F, f$  for the whole moving Forces of the two Systems; I say, that  $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$ .*

For by the *First Proposition*, the Velocities in two corresponding Pipes of the two Systems, setting aside the Resistance of the Air, are in Ratios compounded of the subduplicate Ratios of the Forces generating the Motions in the two Pipes directly, and the subduplicate Ratios of the Diameters and Lengths of the Pipes inversly: But by Supposition the Forces generating

nerating the Motions in the two Pipes are in the same Proportion as the whole moving Forces of the two Systems, and the Capacities of the two Pipes are as the Capacities of the two Systems : And therefore by Proportion of Equality, the Velocities in the two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and the subduplicate Ratios of the Diameters and Lengths of the two Pipes inversely.

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PROOF *by* EXPERIMENTS.

*Experiment I.*

**I** Had two Systems of Cylindrical Pipes made of Brass, each of which consisted of a Trunk and two Branches.

Branches. The larger Branch of each System was a Continuation of its Trunk, having an equal Diameter, and lying in a right Line with it; and the smaller Branch of each made an Angle of 30 Degrees with the larger. The Trunks and Branches of the two Systems were each of them one Foot in Length; the Diameter of the Trunk and larger Branch in the greater System was  $\frac{345}{1000}$ , and the Diameter of the smaller Branch  $\frac{187}{1000}$  parts of an Inch; and the Diameter of the Trunk and larger Branch in the lesser System was  $\frac{187}{1000}$ , and the Diameter of the smaller Branch  $\frac{90}{1000}$  parts of an Inch. The Trunks of the two Systems were successively screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon. In this Situation, the  
Branches



Branches of the greater System discharged  $169\frac{1}{2}$  and 20, and the Branches of the lesser  $30\frac{1}{4}$  and 4 Ounces of Water in half a Minute. The Velocities in the Trunks and Branches of these Systems, found by dividing the Quantities which flow'd through them in a given Time by the Squares of their respective Diameters, were as the Numbers 1592, 1424, and 571 in the Trunk and Branches of the greater System; and as the Numbers 979, 865, and 500 in the Trunk and Branches of the lesser. The Quantities of Water contained in these two Systems, were as the Numbers 273 and 78; as I found by multiplying the Squares of the Diameters of the several Pipes into their Lengths, and then adding the Products of each System into one Sum. Since all the Pipes of the two Systems were at the same perpendicular Distance from the Top  
of

of the Water, and lay parallel to the Horizon, in which Position the Weights of Fluid contained in the Pipes made no part of the Forces generating the Motions of the Water flowing thro' them, the Forces generating the Motions in the Trunks and corresponding Branches, were as the Squares of their Diameters, or as the Quantities of Water contained in them, because they all had the same Length. And therefore had these two Systems been truly made, so as to have had the Conditions required in the *Proposition*, that is, had the Quantities of Water contained in the Trunks and corresponding Branches been exactly proportional to the whole Quantities of Water contained in the two Systems; the Velocities in those Pipes, setting aside the Resistance of the Air, ought to have been in the subduplicate Ratios of their

F

Dia-

Diameters directly. But the Capacity of the lesser Branch of the greater System compared with the Capacity of that System, was greater than the Capacity of the lesser Branch of the lesser System compared with the Capacity of its System, in the Proportion of 128 to 103. The Velocity by Experiment in the lesser Branch of the greater System compared with the Velocity by the Theory, was less than it would have been had the Branch been truly constructed; which agrees with what I have already shewn both from Experiments and Reason, namely, that in Pipes of different Diameters but equal Lengths the Velocity by Experiment compared with the Velocity by the Theory, is always greatest in the narrowest Pipes. The Velocity by Experiment with respect to the Velocity measured by the Square  
Root



Root of the Diameter of the Pipe, was less in the smaller Branch of the greater System than in the smaller Branch of the lesser System, in the Proportion of 21 to 26. As the Capacity of the smaller Branch with respect to the Capacity of the System, was something greater in the greater System than in the lesser; so the Capacity of the Trunk or larger Branch with respect to the Capacity of the System, was on the contrary something less in the greater System than in the lesser; and by Consequence, from what has been said concerning the Nature of the moving Force, the Velocity by Experiment with respect to the Velocity measured by the Square Root of the Diameter of the Pipe, was greater in the Trunk and larger Branch of the greater System than it was in the Trunk and larger Branch of the lesser: In the

Trunk it was greater in the Proportion of 86 to 72, and in the Branch it was greater in the Proportion of 76 to 63. These Deviations of the Theory from Experiments, are not Objections against it, but rather Arguments of its Truth ; since they all arise, and may be accounted for, from the Systems not having exactly the Conditions required in this *Proposition*.

*Experiment II.* Two Systems of Cylindrical Pipes, the lesser of which was the greater of the two Systems used in the last Experiment, and the greater a System four times as great, its Trunk and Branches having the same Diameters, and being four times as long as the Trunk and Branches of the lesser, had their Trunks successively screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and had both their Trunks  
and

and Branches laid parallel to the Horizon: In this Position the Branches of the greater System discharged  $90\frac{3}{4}$ , and  $13\frac{1}{2}$ ; and the Branches of the lesser  $169\frac{1}{2}$ , and 20 Ounces of Water in half a Minute. The Diameters of the Trunks and corresponding Branches of the two Systems being equal; the Velocities in those Pipes were as the Quantities of Water which flow'd thro' them in a given Time, that is, as the Numbers  $104\frac{1}{4}$ ,  $90\frac{3}{4}$ ,  $13\frac{1}{2}$  in the Trunk and Branches of the greater System; and as the Numbers  $189\frac{1}{2}$ ,  $169\frac{1}{2}$ , 20 in the Trunk and Branches of the lesser. The Diameters of the corresponding Pipes of the two Systems being equal, the Pipes lying parallel to the Horizon, and at the same perpendicular Distance from the Top of the Water; the moving Forces of the two Systems were equal, as were the moving



ving Forces of any two of their corresponding Pipes ; and the Quantities of Water contained in the Systems were as the Quantities contained in their Trunks, or in any two of their corresponding Branches, which Quantities were as the Lengths of those Pipes, their Diameters being equal ; and therefore by this *Proposition*, the Velocities in the corresponding Pipes of the Systems ought to have been in the subduplicate Ratios of the Lengths of those Pipes, that is, they ought to have been twice as great in the Trunk and Branches of the shorter System as in the Trunk and corresponding Branches of the longer, as they nearly were ; only they were something greater than they ought to have been in the longer System, from a less Resistance of the Air, and from the Nature of the moving Force, which from what has  
been

been said concerning its Measure, was something greater in the longer System than in the shorter.

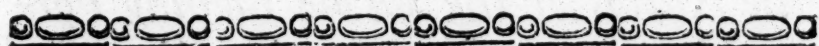
*Experiment III.* I placed the two Systems, used in the last Experiment, at different perpendicular Distances from the Top of the Water with their Trunks and Branches parallel to the Horizon; and always found the Velocities in the Trunk and Branches of each System to be nearly in the subduplicate Ratios of the perpendicular Distances of the System from the Top of the Water; only at less Distances they were something less than they ought to have been by this Measure, for the Reasons assigned in the third Experiment of the first *Proposition*.

*Experiment IV.* The two Systems used in the second and third Experiments, were one after the other screw'd into the Side of the Vessel at different perpendicular Distances from

from the Top of the Water, the lesser at the Distance of one Foot, and the greater at the Distance of four Feet, and were turned till the lesser Branch of each System was depressed in an Angle of 30 Degrees below the Plane of the Horizon, while the Trunk and larger Branch of each System lay parallel to it: The Systems being thus situated, the Branches of the greater System discharged  $89\frac{1}{2}$ ,  $17\frac{1}{2}$ ; and the Branches of the lesser  $79$ ,  $13\frac{1}{4}$  Ounces of Water in half a Minute. The Diameters of the corresponding Pipes being equal; the Velocities in them were as the Quantities of Water which flowed through them in the given Time of the Motion, that is, as  $206\frac{1}{8}$ ,  $89\frac{1}{2}$ ,  $17\frac{1}{8}$  in the Trunk and Branches of the greater System; and as  $92\frac{1}{4}$ ,  $79$ ,  $13\frac{1}{4}$  in the Trunk and Branches of the lesser. The Diameters of the corresponding Pipes being equal,  
and



and the Forces generating the Motions in those Pipes being nearly proportional to the Quantities of Water contained in them, and the whole moving Forces of the two Systems being nearly proportional to their whole Quantities of Fluid; the Velocities in the corresponding Pipes ought to have been equal by this *Proposition*. The Differences were not great, and probably arose chiefly from the lesser System being placed nearer to the Top of the Water than the greater.



### Proposition III.

**I**F a Fluid flow thro' two Systems of Cylindrical Pipes made of a given Sort of Matter, and consisting each of two Trunks, and the same Number of Branches similar in their Situations and Capacities, that is, if  
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any

any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be as the Capacities of their whole Systems, if in each System the last and smallest Branches of the two Trunks be continuous, and if the Forces generating the Motions in any two corresponding Pipes be in the same Proportion as the whole moving Forces of the two Systems; The Velocities in two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversely, that is,

$$V. v :: \sqrt{\frac{F}{DL}} \cdot \sqrt{\frac{f}{d l}}.$$

For by the First Proposition, the Velocities in two corresponding Pipes

Pipes of the two Systems, setting aside the Resistance of the Air, are in Ratios compounded of the subduplicate Ratios of the Forces generating the Motions in the two Pipes directly, and the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversely: But by Supposition, the Forces generating the Motions in two corresponding Pipes, are as the whole moving Forces of the two Systems, and the Capacities of two corresponding Pipes, as the whole Capacities of the two Systems: And therefore by Proportion of Equality, the Velocities in two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and the subduplicate Ratios of the Diame-



ters and Lengths of the two Pipes taken together inverfly.



PROOF *by* EXPERIMENTS.

**T**O examine the Truth of this *Proposition* by Experiments, I got made of Brass two such Systems of Cylindrical Pipes as are represented in these Figures. Each System consisted of two Trunks and five Branches all lying in one and the same Plane. The Trunks and Branches of each had equal Diameters and Lengths. The common Diameter of the Trunks and Branches of the greater System, was  $\frac{137}{1000}$ ; and the common Diameter of the Trunks and Branches of the lesser System, was  $\frac{90}{1000}$  parts of an Inch. The common Length of the Trunks and Branches of the greater System, was half a Foot; and the common Length

Length of the Trunks and Branches of the lesser, three Inches. The Trunks of each System opened into the Branches, through two triangular Spaces which were each three Inches long in the greater System and an Inch and a half in the lesser; and their Capacities were nearly in the same Proportion as the Capacities of their Trunks or Branches, that is, in the Proportion of 87 to 10. When the Ends F and f were screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon; their other Ends G and g discharged  $36\frac{5}{8}$  and  $8\frac{1}{8}$  Ounces of Water in half a Minute. The Velocities in the Trunks, found by dividing the Discharges by the Squares of their Diameters, were as the Numbers 26 and 25 nearly. And the Velocities

ties by this *Proposition* ought to have been as the Numbers 96 $\frac{1}{2}$  and 95, which are proportional to the Numbers 26 and 25 very nearly. And since the Systems were similar, and similarly situated, no Doubt can be made, but that the Velocities in corresponding Branches were likewise in the same Proportion.

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#### Proposition IV.

**I***F a Fluid flow thro' two compounded Systems of Cylindrical Pipes, consisting each of two Cylindrical Trunks, and the same Number of smaller Systems, like those described in the last Proposition, the Trunks of which smaller Systems open into their respective principal Trunks of the compounded Systems, if all the corresponding Pipes of the compounded Systems have like Situations and Capacities, that is, if any*  
two



*two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be in the same Proportion as the whole Capacities of the compounded Systems, and if the Forces generating the Motions in two corresponding Pipes be as the whole moving Forces of the two compounded Systems; the Velocities in two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two compounded Systems directly, and the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversely, that is,  $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$ .*

The Demonstration of this Proposition is the same with that of the last, and therefore need not be repeated.

Cor.

*Cor. 1.* If the whole moving Forces of the two compounded Systems be as the Capacities of the Systems, and consequently as the Capacities of two corresponding Pipes; the Velocities in those Pipes, setting aside the Resistance of the Air, will be in the subduplicate Ratios of the Diameters of the Pipes. If  $F.f :: D^2 L. d^2 l$ ; then will  $V.v :: \sqrt{D}. \sqrt{d}$ .

*Cor. 2.* If the whole moving Forces of the two compounded Systems be as the Capacities of the Systems, and consequently as the Capacities of two corresponding Pipes, and the Diameters of the corresponding Pipes be in the subduplicate Ratios of their Lengths, or of the Lengths of the Systems; the Velocities in corresponding Pipes, setting aside the Resistance of the Air, will be in the subquadruplicate Ratios of the Lengths of the Systems. If  
F.

$F.f::D^2L.d^2l$ , and  $D.d::\sqrt{L}.\sqrt{l}$ ;  
then will  $V.v::L^{\frac{1}{4}}.l^{\frac{1}{4}}$ .

*Cor. 3.* If the whole moving Forces of the two compounded Systems be as the  $m$  Power of the Capacities of the Systems, and consequently as the  $m$  Power of the Capacities of two corresponding Pipes, and the Diameters of the Pipes be as the  $n$  Power of their Lengths, or as the  $n$  Power of the Lengths of the Systems; the Velocities in two corresponding Pipes, setting aside the Resistance of the Air, will be in the  $\frac{2nm+m-n-1}{2}$  Power of the Lengths of the Systems. If  $F.f::D^2L^m.d^2l^m$ , and  $D.d::L^n.l^n$ ; then will  $V.v::L^{\frac{2nm+m-n-1}{2}}.l^{\frac{2nm+m-n-1}{2}}$ .

*Cor. 4.* The whole moving Forces of the two compounded Systems are in Ratios compounded of the  
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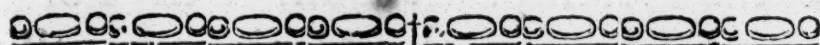


duplicate Ratios of the Velocities in two corresponding Pipes, and the simple Ratios of their Diameters and Lengths, that is,  $F . f :: V^2 D L . v^2 d l$ .

*Scholium.*

This *Proposition* will hold true, if the two Systems be made of Conical Pipes equal in their Capacities and Lengths to the Cylindrical ones, and so constructed, as that the greatest or least Diameters of two corresponding Conical Pipes shall every where bear the same Proportion to each other, as the Diameters of the two Cylindrical Pipes which are equal to them.

Pro-



## Proposition V. Problem I.

**T**HE Velocity of a Fluid moving through a Cylindrical Pipe of a given Diameter and Length and the Force generating the Motion being given; to determine the Velocities generated by an equal Force in the several Parts of a System like one of the Systems described in the Third Proposition, which System consists of two given Cylindrical Trunks and a given Number of Cylindrical Branches into which the two Trunks open.

The two Forces generating the Motions in the Cylindrical Pipe and in this System being equal by Supposition; their Measures will likewise be equal, which Measures may be had from *Cor. 7. Prop. I.* For the Force generating the whole Motion

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of the System, is the Sum of the Forces generating the Motions in all its Parts ; and the Measures of the Forces generating the Motions in the several Parts of the System, may be expressed by that *Corollary*. Putting  $L$  for the Length of the Cylindrical Pipe,  $D$  for its Diameter,  $V$  for the Velocity of the Fluid moving through it ;  $l$  for the Length of that Trunk through which the Fluid flows into the System,  $d$  for its Diameter, and  $x$  for the Velocity of the Fluid flowing through it ;  $\Lambda$  for the mean Length of the Branches,  $\Delta$  for the Diameter of a Cylinder whose Length is that mean Length, and whose Orifice is equal to the Sum of the Orifices of all the Branches ;  $\lambda$  for the Length of the other Cylindrical Trunk, and  $\delta$  for its Diameter : the Measure of the Force generating the Motion of the Fluid flowing thro' the Cylindrical  
Pipe



Pipe is  $V^2 D L$ ; and the Measure of the Force generating the Motion in that Trunk through which the Fluid flows into the System is  $x^2 d l$ : The mean Velocity in the Branches, is to  $x$  the Velocity in that Trunk, as  $d^2$ , is to  $\Delta^2$ , because the Velocities of the same Quantity of Fluid flowing through two Cylindrical Pipes in the same time, are reciprocally proportional to the Squares of their Diameters; whence the mean Velocity in the Branches is  $\frac{x d^2}{\Delta^2}$ ; and the Measure of the Force generating the Motion in the Branches taken all together, is  $\frac{x^2 d^4 \Delta}{\Delta^3}$ : By the same Reasoning the Velocity in the other Trunk thro' which the Fluid flows out of the System, is  $\frac{x d^2}{\delta^2}$ ; and the Measure of the Force generating the Motion of the Water flowing thro'

thro' it, is  $\frac{x^2 d^4 \lambda}{\delta^3}$  : But the Sum of the Forces generating the Motions in all the Parts of the System, is by Supposition equal to the Force generating the Motion in the Cylindrical Pipe; and by Consequence,

$$x^2 d l + \frac{x^2 d^4 \Lambda}{\Delta^3} + \frac{x^2 d^4 \lambda}{\delta^3} = V^2 D L,$$

whence  $x$  is equal to  $\sqrt{\frac{V^2 D L}{d l + \frac{d^4 \Lambda}{\Delta^3} + \frac{d^4 \lambda}{\delta^3}}}$ .

If this Value of  $x$  be substituted in its Room in  $\frac{x d^2}{\Delta^2}$ , the Measure of the mean Velocity in the Branches; that Measure will become  $\frac{d^2}{\Delta^2}$

$$\sqrt{\frac{V^2 D L}{d l + \frac{d^4 \Lambda}{\Delta^3} + \frac{d^4 \lambda}{\delta^3}}}.$$

If the said Value of  $x$  be substituted in its Room in  $\frac{x d^2}{\delta^2}$ , the Measure of the Velocity in the other Trunk;

Trunk ; that Measure will become

$$\frac{d^2}{s^2} \sqrt{\frac{V^2 DL}{dl + \frac{d^4 \Delta}{\Delta^3} + \frac{d^4 \lambda}{s^3}}}.$$

*Cor. 1.* If the Capacity of the Branches be enlarged by an Enlargement of their Diameters or an Encrease of their Number, that is, if  $\Delta$  be encreased, all other Things continuing the same ; the Velocities generated by a given Force, will be greater in the Trunks and less in the Branches than they were before this Change happened in the Capacity of the Branches.

*Cor. 2.* If the Capacity of the Branches be lessened by a Contraction of their Diameters or a Decrease of their Number, that is, if  $\Delta$  be diminished, all other Things continuing the same ; the Velocities generated by a given Force, will be less in the Trunks and greater  
in



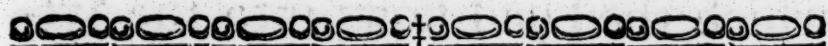
in the Branches than they were before this Change was made in the Capacity of the Branches.

*Cor. 3.* If the two Trunks of the System be given; the Velocities generated by a given Force, will be greatest in the Trunks and least in the Branches when  $\Delta$  is infinite, in which Case the Term  $\frac{d^4 \Lambda}{\Delta^3}$  will vanish or become nothing: The Velocity in the Trunk through which the Fluid flows into the System will be  $\sqrt{\frac{V^2 DL}{dl + \frac{d^4 \Lambda}{\delta^3}}}$ : The Velocity in the Branches will be infinitely little: And the Velocity in the other Trunk will be  $\frac{d^2}{\delta^2} \sqrt{\frac{V^2 DL}{dl + \frac{d^4 \Lambda}{\delta^3}}}$ .

*Cor. 4.* If the Velocity in the given Cylindrical Pipe be equal to the

the Velocity in that Trunk thro' which the Fluid flows into the System, that is, if  $V$  be equal to  $x$ , and consequently  $V^2$  equal to  $x^2$ , and if the Diameter of the given Cylindrical Pipe, be equal to the Diameter of that Trunk through which the Fluid flows into the System, that is, if  $D$  be equal to  $d$ ; then the Length of the Cylindrical Pipe or  $L$ , will be equal to  $1 + \frac{d^3 \Lambda}{\Delta^3} + \frac{d^3 \lambda}{\delta^3}$ .

*Cor. 5.* If the Branches taken together, be wider than either of the Trunks; the mean Velocity in them will be less than it is in the Trunks: and if one Trunk be wider than the other; the Velocity will be as much less as the Trunk is wider.



PROOF *by* EXPERIMENTS.

THE greater of the Systems which were made for the Proof of the *Third Proposition*, was screwed into the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and was turned till its Branches were parallel to the Horizon. The Branches of this System were so contrived, that their Ends next to the Vessel could be opened or shut by little Brass Sliders fixed to the Plate thro' which those Pipes passed, which Sliders being moved up or down, opened or shut the Ends of the Branches. This System being thus situated, when the Branch C only was open; the Trunk G discharged 29½ Ounces of Water in half a Minute;



nute: When the three Branches b, c, d were open, it discharged 36 Ounces: And when all the five Branches were open, it discharged  $36\frac{5}{8}$  Ounces in the same Time. The Velocities in the two equal Trunks, were as the Quantities discharged. When one Branch only was open, the Velocity in that Branch, was equal to the Velocity in the Trunk; and therefore the Velocity in the Branch C, when the rest of the Branches were shut, was as  $29\frac{1}{2}$ . The mean Velocity in the three Branches, found by applying 36 to 3 the Sum of their Orifices, the Orifice of each of the Trunks being 1, was as 12: and the Velocity in the five Branches, when they were all open, found by dividing  $36\frac{5}{8}$  by 5, was as  $7\frac{13}{40}$ . These were the true Velocities in the Trunks and Branches in these three Experiments. I shall

now shew what they ought to have been by this Problem.

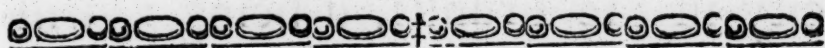
The two Trunks and Branch C taken together, may be considered as one Cylindrical Pipe ; and therefore may represent the given Cylindrical Pipe in this Problem, in which the Velocity  $V$  is as  $29\frac{1}{2}$ . The Trunks and Branches of this System having all equal Diameters,  $D, d,$  and  $\lambda$  were equal. The Lengths of the two Trunks were equal, and when added together, their Sum was equal to the Length of the Branches added to the Lengths of the two triangular Spaces into which they opened ; therefore  $l$  was equal to  $\lambda$ , and  $l + \lambda$  equal to  $\Lambda$  if the triangular Spaces be considered as Parts of the Branches, on which Supposition  $L$  was equal to  $l + \lambda + \Lambda$  ; and by Consequence equal to two Feet ; for  $l$  and  $\lambda$  were each half a Foot, and  $\Lambda$  one Foot. The Velocity

city in the Trunks,  $d$  being 1, will be expressed by  $\sqrt{\frac{1740\frac{1}{2}}{1 + \frac{1}{\Delta^3}}}$ ; therefore when three Branches were open, and by Consequence  $\Delta$  equal to  $\sqrt{3}$ ; the Velocity ought to have been nearly as 38: And nearly as 40; when all five were open, and  $\Delta$  equal to  $\sqrt{5}$ .

The Velocities in the Branches, expressed by  $\frac{d^2}{\Delta^2} \sqrt{\frac{1740\frac{1}{2}}{1 + \frac{1}{\Delta^3}}}$ , ought to have been  $12\frac{2}{3}$ , when three Branches were open; and 8, when all five were open. The near Agreement of these Velocities with those from Experiments, shews the Velocities in the Trunks and Branches of this System to be rightly determined by this Problem.

Pro-





## Proposition VI.

**I**F a Fluid flow through a simple System of Cylindrical Pipes, consisting of one Trunk and a certain Number of Branches; the Velocity in any Pipe will be greater or less, as the moving Force of the System is greater or less, as the Pipe is wider or narrower, shorter or longer, nearer to or farther from the moving Force, as the Weight of Fluid in the Pipe conspires with or opposes its Motion, or as any of the other Pipes of the System is lengthened or shortened.

That the Velocity in any Pipe of this System is greater or less, as the moving Force of the System is greater or less, as the Pipe is wider or narrower, shorter or longer, or as the Weight of Fluid contained in  
the

the Pipe conspires with or opposes its Motion; has been fully proved in the foregoing *Propositions*. And that the Velocity is greater or less, as the Pipe is nearer to or farther from the moving Force, may be thus proved. From the Nature of this Motion, the whole moving Force is resisted by the Quantity of Fluid contained in the whole System: And that part of this Force which moves the Fluid through any Pipe, is resisted by the Quantity of Fluid in that part of the System which lies before it; the Resistance therefore will be greater or less, as a Pipe is nearer to or farther from the moving Force: But as the Resistance is greater or less, the Pressure of the moving Fluid against the Orifice of the Pipe, and consequently the Velocity in the Pipe, is greater or less; and therefore, *ceteris paribus*, the Velocity in a Pipe is greater

greater or less, as it is nearer to or farther from the moving Force. Lastly, the Velocity in a Pipe will be greater or less, *cæteris paribus*, as any of the other Pipes of the System is lengthened or shortened: For by lengthening or shortening a Pipe, the Resistance given by the Fluid contained in it to that part of the moving Force of the System which is spent on that Pipe, becomes greater or less than it was before: But a greater or less Resistance makes the moving Force to act more or less powerfully on the other Pipes, and encreases or lessens the Velocities in them: And therefore the Velocity in a Pipe will be encreased or lessened, *cæteris paribus*, as any of the other Pipes is lengthened or shortened.

PROOF

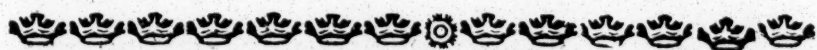




the same Plane, and were placed at the Distances of four, nine, and sixteen Feet from the moving Force of the System, or that End of the Trunk which was screwed into the Side of the Vessel. The Branches, beginning with that which lay nearest to the moving Force, discharged in the same Time Quantities of Water, which were as the Numbers 9, 6, and 5. The Branches having equal Diameters, the Velocities in them were as the Quantities discharged; and therefore, the Velocity in a Pipe is greater or less, *ceteris paribus*, as the Pipe is nearer to or farther from the moving Force.

A given Branch at the Distance of one Foot from the moving Force discharged 20 Ounces of Water in half a Minute, when the Length of the Trunk was two Feet; and 36 Ounces in the same Time, when the  
Length

Length of the Trunk was encreased to eight Feet. And the same Change of Velocity, but in a less Degree, was produced by lengthening any of the other Branches; and therefore, the Velocity in a given Pipe will be greater or less, *cæteris paribus*, as any of the other Pipes of the System is lengthened or shortened.



### Proposition VII.

**I**F a Fluid flow through a simple System of Cylindrical Pipes, consisting of one Trunk and a certain Number of Branches; and if any Pipe of the System be obstructed or opened, contracted or dilated; the Velocity will be encreased or diminished in all the other Pipes of the System: And the Increase or Diminution of Velocity in any one of

K 2 them,



*them, will be greater or less, cæteris paribus, as the Pipe is nearer to or farther from the obstructed or opened, contracted or dilated Pipe.*

Since to obstruct or contract a Pipe, is in Effect to lengthen it; and to open or dilate it, is in Effect to shorten it; the first part of this *Proposition*, is true by the last *Proposition*: And the second part of it is thus proved. When a Pipe is obstructed or contracted, that part of the moving Force which before this Change generated the Motion destroyed in the obstructed or contracted Pipe, is not lost, but spent in increasing the Motions in the other Pipes which are open, and may be considered as a new Force apply'd to the System at the Place of Obstruction or Contraction, and propagated from thence to all the other Pipes of the System; and there-

therefore, by the last *Proposition*, the Velocities generated in those Pipes by this new Force, will be greater or less, as the Pipes are nearer to or farther from the Force, that is, as they are nearer to or farther from the Place of Obstruction or Contraction. And the contrary must happen, when a Pipe is opened or dilated; the Velocities will then be diminished in all the other Pipes, and its Diminution will be greater or less, *cæteris paribus*, as the Pipes are nearer to or farther from the Place of Aperture or Dilatation: And therefore the *Proposition* is true.

*Cor.* If the simple System be so constructed, that the Velocities in its Trunk and Branches be respectively equal to the Velocities in that principal and those lesser Trunks of such a compounded System of Cylindrical Pipes as I have described in the fourth *Proposition*  
and

and its *Scholium*, through which Trunks the Fluid flows into the compounded System and lesser Systems of which it is composed; then, whatever Change is made in the Velocities of two corresponding Pipes of the two Systems, that Change will produce like Changes of Velocity in all the other corresponding Pipes; and by Consequence, when the Velocity is lessened in any one of the said lesser Trunks of the compounded System; it will be increased in all the others, and its Increase will be greater or less, *cæteris paribus*, as the Trunks are nearer to or farther from that in which the Velocity is lessened: And when the Velocity is increased in one of the said lesser Trunks, it will be lessened in all the rest: And its Diminution will be greater or less, *cæteris paribus*, as they are nearer to or farther from  
that



that Trunk in which the Velocity is increased.



PROOF *by* EXPERIMENTS.

A System of Cylindrical Pipes had five Branches, A, B, C, D, E, of equal Diameters and Lengths. The Branch A lay nearest to the moving Force, then B, and so on in the Order they are mentioned. The Velocities in these Branches, obtained from the Quantities of Water discharged in a given Time, were as the Numbers  $94\frac{2}{3}$ , 68, 52,  $36\frac{1}{3}$ ,  $19\frac{1}{7}$ , when the End of the Trunk was open; and as the Numbers 98,  $76\frac{1}{4}$ ,  $70\frac{1}{2}$ ,  $66\frac{1}{2}$ ,  $61\frac{1}{8}$ , when the End of the Trunk was shut; and the Differences of the Velocities in the same Pipes, when the End of the Trunk was open and shut, were  $3\frac{1}{3}$ ,  $8\frac{1}{4}$ ,  $18\frac{1}{2}$ ,  $30\frac{1}{6}$ ,  $42\frac{1}{42}$ .

$42\frac{1}{2}$ . When the Branch C was shut, the Velocities in the Branches A, B, D, E, were as the Numbers  $99\frac{1}{2}$ ,  $81\frac{1}{2}$ ,  $43\frac{1}{4}$ ,  $23\frac{1}{3}$ ; and the Differences of these Velocities and the Velocities in the same Branches, when C was open, were  $4\frac{5}{8}$ ,  $13\frac{1}{2}$ ,  $7\frac{1}{2}$ ,  $4\frac{1}{2}$ . And the same Changes of Velocity, but in a lesser Degree, will be produced when a Pipe is only contracted.

If the System had originally had but the four Branches A, B, D, E, and afterwards the Branch C had been added; it is evident from these Experiments, that the Velocities in the original Branches would all have been diminished by the Addition of this new Branch; and that the Diminution of Velocity in any of them would have been greater or less, as it lay nearer to or farther from the Branch C: But the adding a new Pipe to a System, will produce like Changes of Motion in the other Pipes,

Pipes, as the opening or dilating an old Pipe ; for by all these, there will be a like Abatement of the Force generating the Motion in the other Pipes.

Therefore by these Experiments and the *Corollary* of this *Proposition*, when any Pipe of the simple System, or any of the aforesaid Trunks of the compounded System, is obstructed or opened, contracted or dilated ; the Velocity will be encreased or diminished in all the other Pipes of the simple System, and all the rest of the aforesaid Trunks in the compounded System ; and its Increase or Diminution in any one of those Pipes or Trunks, will be greater or less, *cæteris paribus*, as it is nearer to or farther from the Pipe or Trunk which is obstructed or opened, contracted or dilated.



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SECTION II.

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*Of Muscular Motion, the Motion of  
the Blood, and Respiration.*

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*Of Muscular Motion.*

Proposition VIII.

**M**USCULAR Motion is performed by the Vibrations of a very Elastick Æther, lodged in the Nerves and Membranes investing the minute Fibres of the Muscles, excited by the Power of the Will, Heat, Wounds, the subtile and active Particles of Bodies, and other Causes.

Before I enter upon the Proof of this Proposition, it will be necessary to give a short Account of the Structure of a Muscle.

A

A Muscle appears to the Eye, to be composed of two Parts of different Colours, one red, and the other white. The red is called its fleshy, and the white its tendinous Part. Some Muscles are tendinous both at their Origin and Insertion, and fleshy only in their Middle; and others are fleshy at their Origin and in their Middle, and tendinous only at their Insertion. The fleshy Part of a Muscle is composed of Fibres, Membranes, Nerves, Blood-Vessels, and Lympheducts. The Fibres are small Threads, which are shortened when a Muscle is contracted, and lengthened when it is dilated. The Membranes are thin Skins, which run between the Fibres, are fastened to them, and tye them together. If a Piece of Flesh be boiled, till it become very tender, and afterwards be divided and subdivided, as far as the Eye and Hand

can go ; it will appear, that each minute Fibre in the lowest Subdivision, is entirely surrounded by its own particular Membrane. The Membranes, if they be extremely thin, are transparent ; and if they be thicker, they are of a whitish Colour. The Nerves are dispersed throughout the whole fleshy Part, as may be gathered from the Pain which is produced any where in that Part by the smallest Wound. It has been a received Opinion, that the Nerves are small Pipes which contain a Fluid, called *Animal Spirits*, drawn off from the Blood in the Brain. But it does not appear from any Experiments, that the Nerves are Pipes ; or that such a Fluid as they conceive *Animal Spirits* to be, is separated from the Blood in the Brain ; and therefore these Opinions are without any just Foundation. The Nerves are not only impervious



pervious to the smallest *Stylus*, but when viewed with a Microscope, evidently appear to have no Cavity. And when we consider the Manner, in which the Favourers of this Opinion have explained *Muscular Motion* by *Animal Spirits*; we must allow, that such a Fluid is altogether unfit for this Work. For these Reasons, many have thought the Nerves to be solid Threads, extended from the Brain to the Muscles and other Parts of the Body. Sir *Isaac Newton* is of this Opinion, as appears from the following Account he has given of the Nerves, in the 24th *Query* of his *Opticks*. “ I suppose  
 “ that the *Capillamenta* of the  
 “ Nerves are each of them solid  
 “ and uniform, that the vibrating  
 “ Motion of the *Ætherial Medium*  
 “ may be propagated along them  
 “ from one End to the other uniformly, and without Interruption:  
 “ For

“ For Obstructions in the Nerves  
“ create Palsies. And that they  
“ may be sufficiently uniform, I  
“ suppose them to be pellucid when  
“ viewed singly, tho’ the Reflecti-  
“ ons in their Cylindrical Surfaces  
“ may make the whole Nerve  
“ (composed of many *Capillamen-*  
“ *ta*) appear opaque and white. For  
“ Opacity arises from reflecting  
“ Surfaces, such as may disturb and  
“ interrupt the Motions of this Me-  
“ dium.” The Blood-Vessels of a  
Muscle are interwoven in the Mem-  
branes, and distributed throughout  
its whole fleshy Part, as appears from  
its Redness, and from the issuing out  
of Blood from a Puncture made any  
where in it with the finest Needle.  
The Muscles are stocked with Lym-  
phatick Vessels, as well as the other  
Parts of the Body.

I have no farther Occasion to con-  
sider the Structure of a Muscle, what

I have said being sufficient for my Purpose, but shall now proceed to prove the *Proposition* from Experiments and Observations.

It has been found by Observation, that when a Muscle is contracted, its fleshy Fibres are shortened and hardened, without any sensible Change made in its Tendons; that as soon as the Contraction is over, or the contracting Force ceases to act, the shortened and hardened Fibres are lengthened and softened again; that this alternate Motion of Contraction and Dilatation continues in the Hearts of some Animals, especially young ones, for a considerable Time after they are cut out of their Bodies, and laid on a Table; that it generally continues longer in the Hearts of Fish, than in the Hearts of Land-Animals; and that after it has ceased, it will be renewed again by Warmth or the pricking



pricking of a Pin, and will continue to be excited by either, especially Warmth, for some little time, till the Heart wholly loses its Power of moving; that as the Heart cools by Degrees, so its Motion abates gradually, its Contractions and Dilatations growing less and less frequent and strong, till at last they wholly cease; and that the Heat of the Heart is greater, and its Motion more frequent and strong, in an ardent Fever and the hot Fit of an Ague, than in its natural State.

Hence it appears, that Heat is a remote Cause both of the Frequency and Strength of the Motion of the Heart; and consequently, one of the remote Causes of the Motion of a Muscle.

We find by Experience, that by the Power of the Will we can move the Muscles of our Limbs with various Degrees of Force; that there  
is

is not the least sensible Difference in point of Time between willing the Motions of the Muscles, and the Motions themselves; that Muscles contracted by the Power of the Will, dilate again the very Instant in which the Soul ceaseth to exercise that Power; and that the Soul loseth the Power of moving the Muscles, and perceiving Pain from Wounds made in their fleshy Parts, when their Nerves are cut quite through, tied straight, or intirely obstructed any other Way.

Hence it appears, that the Nerves are the Instruments whereby the Will gives Motion to the Muscles: And it does this, by producing some kind of Motion in those Ends of the Nerves which terminate in the Brain, which Motion is propagated from thence thro' their solid, pellucid and uniform *Capillamenta* into

M the

the Muscles. For if the Nerves were intirely at rest, and no Motion was propagated thro' them, they could never by the Power of the Will, or any other Cause, produce Motion in the Muscles.

On laying bare the great Muscle of the hinder Leg of a Dog, and the great Nerve which accompanies the Crural Artery and Vein; I have observed, that when the Tendon was wounded, the Dog shewed very little Uneasiness; but expressed great Pain, on wounding the fleshy Part of the Muscle; and much greater Pain, on wounding, or in the Instant of tying the Nerve; that a Contraction of the Muscle was produced, on wounding its fleshy Part; and a much stronger Contraction on wounding, or in the Instant of tying the Nerve; and that after the Nerve was cut quite through, or  
tied



tied streight, great Uneasiness and Pain with most violent Struggles were produced, as often as a new Wound was inflicted, or a new Ligature made, above the last Section or Ligature, in that Part of the Nerve which communicated with the Brain; but neither Pain nor Contraction of the Muscle followed, on wounding or tying that Part of it which communicated with the Muscle and Limb. And I have likewise observed on trepanning Dogs, and wounding several parts of their Brains, that convulsive Motions of the Limbs have ever been produced, on wounding the *Medulla oblongata*, but never on wounding the *Dura Mater*, or Cortical Part.

Hence likewise it appears, that the Nerves are the principal Instruments of Sensation and Motion; that these Effects are stronger or

M 2

weaker,

weaker, as more or fewer of the nervous *Capillamenta* are tyed or wounded ; that these Effects are the same, in whatever part of a Nerve the Section or Ligature is made ; and that the Soul perceives Pain, and exerts its Power of producing *Muscular Motion*, only at the Origin of the Nerves in the Brain.

The exceeding Quickness of this Motion passing from the Brain thro' the *Capillamenta* of the Nerves to the most distant Muscles in an Instant, and its Cessation the very Moment the Cause which produced it ceases to act, shew it to be the vibrating Motion of a very elastick Fluid. For it is the Nature of the vibrating Motion of an elastick Fluid to be very swift, and to cease the very Instant the Cause which produced it ceases to act. A vibrating Motion excited in our Air  
by

by the Tremors of Bodies for the Production of Sounds, moves at the Rate of 1142 *English* Feet in a second Minute of Time, and ceases the very Instant in which the Tremor of the Bodies cease.

Now since this Motion begun in the Nerves at their Origin, has been proved to be the vibrating Motion of a very elastick Fluid; and since the other Phænomena of Nature absolutely require such an elastick Fluid, as is the *Æther* described by Sir *Isaac Newton*; and since Causes are not to be multiply'd without Necessity: Therefore it must be granted, that this Motion begun in the Nerves at their Origin, is the vibrating Motion of that *Æther*; the Properties of which, gathered from the Phænomena, are these which follow.

*This Æther is exceedingly more rare and subtile than Air, and exceeds*



*ceedingly more elastick and active. It readily pervades all Bodies, and by its elastick Force is expanded thro' all the Heavens. If it be 700000 times more elastick than our Air, it is above 700000 times more rare. Its elastick Force in proportion to its Density, is above 4900000000000 times greater than the elastick Force of the Air is in Proportion to its Density. It is rarer within Bodies, than in the empty Spaces between them; and in passing from Bodies into empty Spaces, it grows denser and denser by Degrees; and the Increase of its Density at any Distance from the Centre of Gravity of a Body, is as the Quantity of Matter in the Body directly, and the Square of that Distance inversely: And it is rarer within dense Bodies, than within rare Bodies. All Bodies endeavour to recede and go from the denser Parts of it, towards the rarer; and the Force wherewith*

*a Body endeavours to recede, is as the Quantity of Matter in the Body, and the Increase of the Density of the Æther at the Centre of Gravity of the Body, taken together. When it is put into a vibrating Motion by the Rays of Light, the Will of Animals, or other Causes; its Vibrations or Pulses move swifter than Light, and by Consequence, above 700000 times swifter than Sounds. Its Density and expansive Force, are both increased in Proportion to the Strength and Vigour of its vibrating Motion; which Motion, like the vibrating Motion of the Air for the Production of Sounds, grows weaker, as the Square of the Distance from the Place in which it is excited increases. And lastly, its vibrating Motion is regularly propagated thro' Bodies made of uniform dense Matter, but is reflected, refracted, interrupted or disordered by any Unevenness in the Bodies.*

These

These are the principal Properties, with which this Æther must necessarily be endued ; which I thought fit to mention, before I shew the Manner in which it causes the Motion of the Muscles.

When by the Power of the Will a vibrating Motion is excited in the Æther, in those Ends of the Nerves which terminate in the Brain ; that Motion is in an Instant propagated thro' their solid and uniform *Capillamenta* to the Membranes of the Muscles, and excites a like Motion in the Æther lodged within those Membranes ; and a vibrating Motion raised in the Æther within the Membranes, increases its expansive Force ; an Increase of that Force swells the Membranes ; a Swelling of the Membranes causes a Contraction of the fleshy Fibres ; and that Contraction, a Motion in the Parts to which the Extremities of the Muscles



Muscles are fastened. Thus the Limbs and other Parts of Animals are moved by their Muscles, each of which has its two Ends fastened to two Bones, whereof one is always more moveable than the other; on which Account, when its fleshy Fibres are shortened by the swelling of the Membranes, the more moveable Bone is drawn towards that which is more fixed, by means of an intervening Joint upon which it turns.

As soon as the Will ceases to act, the vibrating Motion of the Æther caused by that Action ceases; in like manner as the Pulses of the Air causing Sounds cease, on a Cessation of the Tremors of sonorous Bodies, by which they are excited; and a Cessation of the vibrating Motion of the Æther, causes a Diminution of its expansive Force; and a Diminution of that Force,

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gives

gives an Opportunity to the dilated Membranes to contract, by the attractive Powers of their Parts, and thereby to lengthen the fleshy Fibres. Another Cause of the lengthening of the fleshy Fibres and Dilatation of a Muscle, is a vibrating Motion, excited in the Æther lodged in the fleshy Fibres by their Contraction: For that vibrating Motion will increase the expansive Force of the Æther, and that increased Force will lengthen the Fibres, the very Instant the Cause which contracted them ceases to act. These two Forces added together, make the whole Force whereby a contracted Muscle is dilated: For the Experiments above-mentioned fully prove, that the Soul has no immediate Power over the fleshy Fibres. Thus the Muscles of Animals are moved by the Æther, when put into a vibrating

ting Motion by the Power of the Will.

I have shewn that Heat, Punctures or Wounds, and Ligatures on the Nerves in the Instant they are made, have a Power of contracting the Muscles : And from the Effects of vomiting and purging Medicines, and some Poisons, we learn, that the subtile and active Particles of some Bodies have a like Power : But since all these Things, however different they are in themselves, do notwithstanding produce the same Effect which the Will does, they must do it in the same Manner, that is, by exciting a vibrating Motion in the Æther within the Nerves and Membranes of the Muscles. And therefore the *Proposition* is true.

*Cor. 1.* The Motion of the Muscles becomes weak, either from too weak a vibrating Motion of the Æ-



ther in their Membranes and Fibres; or an Unfitness in the Membranes and Fibres to be moved with Vigour by a due Degree of that vibrating Motion. The vibrating Motion excited by a given Force becomes weak, when the Æther becomes rare; and the Æther becomes rare, when the Membranes and Fibres become dense, from Moisture soaking into their Pores, from Compression, or other Causes. And the Membranes and Fibres become unfit to be moved with Vigour, when they are rendered stiff by Age, too hard Labour, or other Causes.

*Cor. 2.* Muscles grow larger and stronger by moderate Exercise: For the expansive Force of the Æther must be increased, before it can move the Muscles; and a frequent Increase of this Force in Muscles much moved, must of Necessity increase

crease both their Magnitudes and Strengths. Hence labouring Persons have larger and stronger Muscles, than Persons who lead a sedentary and inactive Life.

*Cor. 3.* The Blood moving thro' a Muscle, is pressed forward by the Force of its Contraction; but after a Muscle is contracted, if it be kept in that State by the constant Action of the Force which contracted it, less Blood will flow through it in a given Time than did before: For the Blood-Vessels interwoven in the Membranes, are compressed and contracted by the swoln Membranes and shortened and hardened Fibres: And this Contraction of the Vessels, while it is exerting, presses the Blood forward; but afterwards hinders the Blood from flowing through the Muscle in that Quantity it did before. Hence  
Ex-

Exercise performed by the Motion of the Muscles, accelerates the Motion of the Blood; and Cramps and other permanent Convulsions retard it.

*Cor. 4.* The Magnitude of a Muscle may be but little altered by its Contraction : For if the Contraction of the fleshy Fibres be nearly equal to the Swelling of the Membranes, its Magnitude will continue much the same, though its Figure be changed.

*Cor. 5.* The Forces of corresponding Muscles in healthful Bodies, are measured by their Weights, and the Strengths of the vibrating Motions of the Æther in them, taken together.

*Cor. 6.* If a great Increase of the vibrating Motion of the Æther in the Nerves and Membranes of one  
Part



Part of the Body be, *from some Cause*, attended with a Diminution of its vibrating Motion in the Nerves and Membranes of other Parts; then it may be in the Power of Art to quiet a Disturbance in one Part, by raising a stronger Disturbance in another: As by Blisters, Cauteries, and other powerfully stimulating Bodies, applied to one Part of a Human Body, we often relieve Pain, and quiet convulsive Motions in other Parts of it. The Existence and Nature of *such a Cause* I shall consider more fully in its proper Place, it being beside my Design to enlarge upon it at present.

Of

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*Of the Motion of the Blood.*

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## Proposition IX.

**T**HE *Blood moves in the Arteries and Veins with a kind of Circular Motion.*

Harvey has proved this from Experiments and Observations: For he has shewn, that the Blood flows out of the Trunk of the *Vena cava*, into the right Auricle of the Heart; out of that, into the right Ventricle; thence, thro' the Lungs, into the left Auricle and Ventricle; out of the left Ventricle, into the *Aorta*; whose Branches convey it to all Parts of the Body, except the Lungs, and pour it into the smallest Branches of the Veins; out  
of

of which it passes into Branches still larger, till at last, by the *Vena cava* it is brought back to the Heart. And this Motion of the Blood from and to the Heart, is called its *Circulation, or Circular Motion*.

The Heart and Arteries act upon the Blood, in generating and keeping up its Motion, in the following Manner. When the Auricles are filled with Blood by the Veins, the right Auricle by the *Vena cava*, and the left by the Pulmonary Vein, they both contract at one and the same time, and press the Blood which they contain into the Ventricles; and when the Ventricles are filled with Blood, they likewise contract at one and the same Time, and press the Blood which they contain into the Arteries; the right Ventricle into the Pulmonary Artery, and the left into the *Aorta*. The Arteries are dilated by the Blood, forcibly pressed

O                      into



into them by the Ventricles ; and as soon as the Ventricles are emptied, and their Contraction is over, the dilated Arteries contract, and press the Blood forward into the Veins. And thus the Motion of the Blood is generated and kept up, by the Forces of the Heart and Arteries.

The Blood is kept from regurgitating, by the Valves of the Heart and Veins. The Valves at the Entrance of the Auricles into the Ventricles, open when the Auricles contract, and permit the Blood to flow into the Ventricles ; and shut when the Ventricles contract, and prevent its Return into the Auricles. The Valves at the Origins of the *Aorta* and Pulmonary Artery, open when the Ventricles contract, and suffer the Blood to flow into the Arteries ; and shut when the Arteries contract, and hinder

der it from flowing back into the Ventricles. And the Valves of the Veins open to let the Blood move forward towards the Heart ; and shut to prevent its Return into the Arteries.

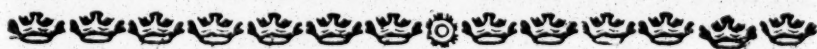
*Cor. 1.* The two Ventricles of the Heart throw out equal Quantities of Blood in each Systole: For if they threw out unequal Quantities ; then, since they always contract together, more or less Blood would flow into the Lungs, than flows out of them, in a given Time: Which must of Necessity soon put an End to Life.

*Cor. 2.* As much Blood flows thro' each Ventricle of the Heart, and through the Lungs ; as flows through all the rest of the Body in the same Time.

*Cor. 3.* The Arteries have a Pulse, and the Veins no Pulse: For the Arteries have a stronger muscular Coat than the Veins, from their sustaining a greater Pressure against their Sides from the Blood forced into them by each Systole of the Heart; and they sustain a greater Pressure against their Sides than the Veins, from a greater Quantity of Blood lying before them, which gives a greater Resistance to the Blood forced into them by the Heart. Now the Sides of both Arteries and Veins being soft and dilatable, it is evident, that the whole System of Vessels must swell, when Blood is forcibly pressed into it by the Heart in its Systole; and endeavour to contract again, when the Force of the Heart ceases to act in its Diastole: But when the Arteries and Veins begin to contract after every Systole of the Heart, the Arteries,



ries by the greater Strength of their Muscular Coat, overpower the Veins; and by pressing the Blood into them, hinder them from contracting: Therefore the Arteries by dilating and contracting, have a Pulse; and the Veins for want of this alternate Motion, have no Pulse.



### Proposition X.

**T**HE *Velocity of the Blood is less in the Sum of the Branches of both Arteries and Veins, than in their respective Trunks; and it is less in the Veins, than in their corresponding Arteries.*

For it has been found by measuring the Vessels, that the Branches of an Artery or Vein taken all together, are wider than the Trunk out of which they arise; and that  
the

the Veins are wider than their corresponding Arteries: And therefore the *Proposition* is true, by the 5th *Corollary* of the 5th *Proposition*.

*Cor. 1.* Hence it appears, that the Velocity of the Blood is continually lessened in the Arteries from their Trunks to their smallest Branches; and increased continually in the Veins from their smallest Branches to their Trunks: And by Consequence, that the Velocity is least in the last and smallest Branches of the Arteries and Veins.

*Cor. 2.* Since the Velocity of the Blood is least in the smallest Branches of the Arteries and Veins; it necessarily follows, that the Blood will be more liable to be obstructed by Cold and other Causes, in its Course thro' those Vessels, than thro' any others.

Proposition



## Proposition XI.

**T**HE *Velocity of the Blood in one and the same Artery or Vein, is the same both in the Systole of the Heart, and in its Diastole; when the Arteries are dilated, and when they are contracted.*

For since the Veins have no Pulse, the Blood must necessarily flow thro' them with the same Velocity when the Arteries are dilated, and when they are contracted; which it could not do, if it moved faster through the Arteries when they are dilated, than when they are contracted; in the Systole of the Heart, than in its Diastole: And therefore the *Proposition* is true.

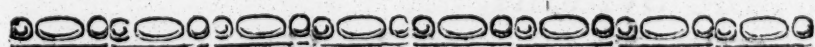
*Cor. 1.* Hence it appears, that while the progressive Motion of the  
Blood



Blood continues the same ; the Force which generates this Motion, must by its constant Action continually generate as much Motion as is destroyed by the Resistance of the internal Surface of the whole System of Blood-Vessels ; otherwise it would be impossible, that the Velocities of the Blood in the same Vessels should be the same in the Systole of the Heart, and in its Diastole ; when the Arteries are dilated, and when they are contracted.

This will not appear strange when we consider, that there are other Motions in Nature which are uniform, notwithstanding the constant Action of a given moving Force. Of this kind is the Motion of a Ship, generated by a Wind blowing constantly and uniformly ; which Motion is at first accelerated, till as much Motion is continually communicated to the Water and  
Air

Air by the Ship moving along; as is generated in it by the constant and uniform Action of the Wind: And after that, it continues uniform, notwithstanding the constant Action of the Wind. Of this kind also, is the Motion of a Body descending in Water; which Motion is accelerated, till the Motion communicated to the Water by the descending Body, becomes equal to the Motion generated in the Body by the constant and uniform Action of its Weight in Water; and after that, the Motion continues uniform, notwithstanding the constant Action of this Weight.



### Proposition XII.

**T**HE *Velocities of the Blood in the corresponding Blood-Vessels of Bodies situated alike with respect*

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*spect to the Horizon, are in the sub-duplicate Ratios of the Diameters of the Vessels, that is,  $V.v :: \sqrt{D}.\sqrt{d}$ .*

For from Anatomy and the Similarity of the corresponding Parts of human Bodies we learn, that their Systems of Blood-Vessels have the same Number of corresponding Vessels; and that corresponding Vessels have like Situations and Capacities, in Bodies situated alike with respect to the Horizon, that is, any two corresponding Vessels are situated alike with respect to the rest of the Vessels, and their Capacities are as the Capacities of the whole Systems.

The Forces of the Hearts are as their Weights, and the Strengths of the vibrating Motions of the Æther in their Nerves and Membranes, taken together, by *Cor. 5. Prop. 8.* But the Strengths of the vibrating  
Motions



Motions of the Æther, setting aside the Power of the Soul and other disturbing Causes, are as the Heats of the Hearts; and the Heats of the Hearts, as the Heats of the Blood; and the Heats of the Blood are much the same in all healthful Bodies, as I have found by the Thermometer: And therefore, setting aside the Power of the Soul and other disturbing Causes, the Forces of the Hearts are as their Weights. The Weights of the Hearts of a strong Man and a Child newly born, were as 16 and 1; the Diameters of their *Aortas* as 2 and 1; and the Lengths of their Bodies as 4, and 1: Now since the Lengths of corresponding Blood-Vessels are as the Lengths of the Bodies, and the Diameters of corresponding Vessels as the Diameters of the *Aortas* in Bodies situated alike with respect to the Horizon; it is evident from this

P 2

Instance,

Instance, that the Weights of the Hearts are as the Capacities of corresponding Vessels, or as the Capacities of the whole Systems, in Bodies situated alike with respect to the Horizon: And therefore the Forces of the Hearts, when they are not disturbed by the Power of the Soul or other Causes, are as the Capacities of corresponding Blood-Vessels, or as the Capacities of the whole Systems in Bodies so situated; and the Forces generating the Motions in corresponding Vessels, are as the Capacities of those Vessels, and by Consequence, as the whole Forces of their Hearts. And farther if we consider, that the System of Blood-Vessels swells or contracts as the Force of the Heart is increased or lessened by the Soul, Heat or Cold, or other Causes; and on the contrary, that the Force of the Heart is increased or lessened, as  
the

the System swells or contracts by Heat or Cold; no Doubt can be made, but that the Forces of the Hearts are ever proportional to the Capacities of their respective Systems of Blood-Vessels; and that the Forces generating the Motions in corresponding Vessels, are as the whole Forces of their Hearts in Bodies situated alike with respect to the Horizon.

And these Things being true, the *Proposition* is true, by the *First Corollary* of the *Fourth Proposition*.

*Cor. 1.* Hence it appears, that the Velocity of the Blood increases continually from the Birth, till Bodies are arrived at their full Lengths; and afterwards, it increases or lessens in the same Bodies, as their Systems of Blood-Vessels swell or contract, either from an Increase or Diminution of the Quantity, or a Diminution or Increase of the Density of the Blood.

*Cor.*



*Cor. 2.* When healthful Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of disturbing Causes; the Velocities of the Blood in corresponding Blood-Vessels, are in Ratios compounded of the subquadruplicate Ratios of the Quantities of Blood contained in their whole Systems of Blood-Vessels directly, and the subquadruplicate Ratios of the Lengths of the Bodies inversely. For the Heat of the Blood is the same in Bodies under these Circumstances, as I have found by the Thermometer, and consequently its Density is given; but the Density of the Blood being given, the Capacities of corresponding Blood-Vessels will be as the Quantities of Blood contained in them, or as the Quantities contained in the whole Systems; therefore, putting  $Q$  and  $q$  for the Quantities contained in

two

two whole Systems,  $D^2L. d^2l :: Q. q;$

whence  $\sqrt{D}. \sqrt{d} :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}}. \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}$ : But by

this *Proposition*,  $V. v :: \sqrt{D}. \sqrt{d}$ ; and therefore in Bodies under the Circumstances mentioned in this *Co-*

*rollary*,  $V. v :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}}. \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}.$

*Cor. 4.* If two healthful Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon, and their Hearts be free from the Influences of disturbing Causes; the Velocities of the Blood in any two corresponding Blood-Vessels of the two Bodies, or in any one and the same Blood-Vessel of the same Body at two different Times, will be in the subquadruplicate Ratios of the whole Quantities of Blood contained

tained in the two Bodies, or in the same Body at those different Times, by the last *Corollary*: If  $L=1$ ; then will  $V. v :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$ .

That the Velocities of the Blood as they are expressed in this *Corollary*, may be found out more easily, I have added the following Table: Which in the two Columns under  $Q$ , contains different Quantities of Blood; and in the two Columns under  $V$ , different Velocities expressed in the biquadrate Roots of those Quantities. For Instance, if the Quantities of Blood in two different Bodies of equal Lengths, or in one and the same Body at two different Times, be as 20 and 18; the Velocities in the corresponding Blood-Vessels of the two Bodies, or in the same Blood-Vessel of the same Body at different Times, will be as the Numbers 21147 and 20597, if the



ANIMAL OECONOMY. 121  
the Bodies be under the Circumstances supposed in this *Corollary*.

Q	V	Q	V
1	10000	26	22581
2	11892	27	22745
3	13160	28	23003
4	14142	29	23206
5	14953	30	23403
6	15650	31	23596
7	16265	32	23784
8	16817	33	23968
9	17320	34	24147
10	17790	35	24323
11	18211	36	24495
12	18612	37	24663
13	18988	38	24828
14	19343	39	24990
15	19680	40	25149
16	20000	41	25304
17	20302	42	25457
18	20597	43	25607
19	20878	44	25755
20	21147	45	25900
21	21407	46	26043
22	21657	47	26183
23	21899	48	26321
24	22134	49	26457
25	22361	50	26591

Q

Cor.

*Cor. 4.* If the Diameters of corresponding Blood-Vessels be in the subduplicate Ratios of the Lengths of the Bodies; the Velocities in those Vessels will be in the subquadruplicate, and the Capacities of the whole Systems in the duplicate Ratios of the Lengths of the Bodies. If  $D. d :: \sqrt{L. l}$ ; then will  $V. v :: L^{\frac{1}{4}}. l^{\frac{1}{4}}$ , and  $D^2 L. d^2 l :: L^2. l^2$ .

From the Instance mentioned in the Proof of this *Proposition* it is evident, that these Proportions of the Diameters of corresponding Blood-Vessels and of the Capacities of the whole Systems obtain in some Bodies, when situated alike with respect to the Horizon; and it is as certain, that they do not obtain in all Bodies so situated; because of Bodies of the same Length, some, from a different Use of the Non-naturals or other Causes, have larger

ger Blood-Vessels than others : Now if these Proportions be observed in the most perfect and best proportioned Bodies, they will likewise obtain in all Bodies of different Lengths, taking those of each Length one with another, when they are situated alike with respect to the Horizon, that is, the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths so situated, each Mean being taken from a considerable Number of Diameters of corresponding Blood-Vessels of Bodies of the same Length, will be in the subduplicate ; and the mean Capacities of the whole Systems in the duplicate Ratios of the Lengths of the Bodies : Otherwise there could be no Regularity and Uniformity preserved in the Species.



Lengths in Inches.	Velocities.	Capacities of the Sys- tems.
72	2913	5184
66	2850	4356
60	2783	3600
54	2711	2916
48	2632	2304
42	2546	1764
36	2449	1296
30	2340	900
24	2214	576
18	2059	324

This Table contains in the first Column, the Lengths of Bodies in Inches; in the second, the true or mean Velocities of the Blood in the corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon; and in the third, the true or mean Capacities of the whole Systems of Blood-Vessels of Bodies of those Lengths. For Instance,

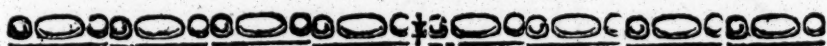
stance, the true or mean Velocities of the Blood in the corresponding Blood-Vessels of Bodies alike situated whose Lengths are 72 and 36, are as the Numbers 2913 and 2449; and the true or mean Capacities of their whole Systems of Blood-Vessels, as the Numbers 5184 and 1296.

*Cor. 5.* If the Diameters of corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon, be as the  $n$  Power of the Lengths of the Bodies; the Velocities in those Vessels will be as the  $\frac{n}{2}$  Power; and the Capacities of the whole Systems, and Quantities of Blood if the Forces of the Hearts are not disturbed, as the  $2n+1$  Power of the Lengths of the Bodies, that

is,  $V. v :: L^{\frac{n}{2}}. l^{\frac{n}{2}}$ , and  $D^2 L. d^2 l :: L^{2n+1}. l^{2n+1}$ , and  $Q. q :: L^{2n+1}. l^{2n+1}$  if  $D^2 L. d^2 l :: Q. q$ .

For

For Example, If the Diameters of corresponding Vessels be in the subtriplicate Ratios of the Lengths of the Bodies, and the Lengths of the Bodies be 72 and 18; the Velocities will be as the Numbers 126 and 100; and the Capacities of the Systems and Quantities of Blood, as the Numbers 10 and 1.



### Proposition XIII.

**T**HE *Velocities of the Blood in the corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon, are in Ratios compounded of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole directly, and of the duplicate Ratios of the Diameters of the Vessels and the simple Ratios of the Times of one Systole inversly. If K, k denote the*  
Mag-



*Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Systole, and T, t the Times of one Systole; I say, that*  $V. v :: \frac{K}{D^2 T} \cdot \frac{k}{d^2 t}.$

For the Velocities of the Blood in any two corresponding Blood-Vessels, are directly as the Spaces described by the Blood in the Times of one Systole, and inversly as those Times: But the Spaces described by the Blood in the Times of one Systole, are as the Magnitudes of the Quantities of Blood which flow into those Vessels in the Times of one Systole apply'd to the Orifices or Squares of the Diameters of the Vessels; and the Magnitudes of those Quantities are as the Magnitudes of the Quantities thrown out of their Hearts in one Systole, if the Bodies be situated alike with respect  
to

to the Horizon : And therefore, the Velocities in the corresponding Blood-Vessels of Bodies so situated, are in Ratios compounded of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole directly, and of the duplicate Ratios of the Diameters of the Vessels and the simple Ratios of the Times of one Systole inversely : Which was to be proved.

*Cor. 1.* If the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Systole, be as the Capacities of any two corresponding Blood-Vessels ; the Velocities in those Vessels will be as the Lengths of the Bodies directly, and as the Times of one Systole of their Hearts inversely. If  $K. k :: D^2L. d^2l$  ; then will  $V. v :: \frac{L}{T} \cdot \frac{l}{t}$ .

This

This *Corollary* obtains in Bodies which are situated alike with respect to the Horizon, and whose Hearts are not influenced by disturbing Causes: For the Hearts of Bodies under these Circumstances, will throw out in each Systole Quantities of Blood whose Magnitudes are equal to the Capacities of their Ventricles; but the Capacities of the Ventricles are as the Magnitudes of the Hearts; and the Magnitudes of the Hearts are as their Weights; (for I have found their Densities to be so nearly equal, that their Differences may be neglected) and the Weights of the Hearts are as their Forces; and their Forces as the Capacities of corresponding Blood-Vessels by the *Proof* of the 12th *Proposition*; and therefore  $K.k :: D^2 L. d^2 l$ .

*Cor. 2.* The true Times of one Systole of the Hearts of regular and  
R well-



well-proportioned Bodies of different Lengths, and the mean Times of one Systole of the Hearts of all Bodies of different Lengths, each Mean being taken from a considerable Number of Bodies of the same Length, are, when the Bodies are situated alike with respect to the Horizon and their Hearts are free from the Influences of all disturbing Causes, as the biquadrate Roots of the Cubes of the Lengths of the Bodies, that is,  $T.t :: L^{\frac{3}{4}}.l^{\frac{3}{4}}$ . For in these Cases,  $V.v :: L^{\frac{1}{4}}.l^{\frac{1}{4}}$  by the 4th Corollary of the 12th Proposition, and  $V.v :: \frac{L}{T} \frac{l}{t}$  by the preceding Corollary of this Proposition; and therefore  $L^{\frac{1}{4}}.l^{\frac{1}{4}} :: \frac{L}{T} \cdot \frac{l}{t}$ ; whence  $T.t :: L^{\frac{3}{4}}.l^{\frac{3}{4}}$ .

Pro-

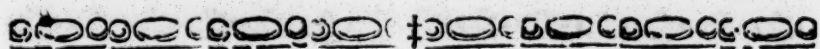


## Proposition XIV.

**T**HE *Velocities of the Blood in the corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon, are in Ratios compounded of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole and the simple Ratios of the Numbers of their Pulses in a given Time directly, and the duplicate Ratios of the Diameters of the corresponding Vessels inversty.* If  $P, p$  denote the Numbers of Pulses in a given Time of two Bodies situated alike with respect to the Horizon; then will  $V. v :: \frac{KP}{D^2} \cdot \frac{kp}{d^2}.$

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PROOF

PROOF *by* EXPERIMENTS.

**I** Took the Pulses in a Minute, and measured the Lengths, of a great Number of Bodies : I took the Pulses when the Bodies were sitting, that they all might be situated alike with respect to the Horizon ; and in the Morning before Breakfast, that their Hearts might be as free as possible from the Influences of all disturbing Causes : And when I had got a very large Stock of Observations, I took the Means of the Pulses, each Mean from a considerable Number of Bodies of the same Length ; and found those Means to be nearly as the biquadrate Roots of the Cubes of the Lengths of the Bodies inverſly, that is, nearly as the mean Times of a Syſtole of their Hearts inverſly, by *Cor. 2. Prop. 12.*

And



And since the mean Numbers of Pulses in a Minute of all Bodies, are the true Numbers of Pulses in a Minute of single Bodies of the same Lengths which are regular and well-proportioned, the Numbers of Pulses in a Minute of regular and well-proportioned Bodies taken singly, will likewise be as the biquadrate Roots of the Cubes of their Lengths, that is, as the Times of a Systole of their Hearts inverfly by the afore-said *Corollary*. Now since in these Instances, the Numbers of Pulses in a Minute are inverfly as the Times of one Systole, and there is no Reason why this Proportion should not be universal; I shall therefore conclude, that it is so: And that in all

Bodies,  $P. p :: \frac{1}{T} \cdot \frac{1}{t}$ : But by the last *Proposition*,  $V. v :: \frac{K}{D^2 T} \cdot \frac{k}{d^2 t}$ : And therefore,  $V. v :: \frac{KP}{D^2} \cdot \frac{kp}{d^2}$ .

To

Ages in Years.	Lengths in Inches.	Pulses from Observation.	Pulses by the Theory.
	72	65	65
	68	67	68
	60	72	74
14	55	77	79
12	51	82	84
9	46	90	91
6	42	97	97
3	35	113	111
2	32	120	119
1	28	126	132
$\frac{1}{2}$	25	137	144
0	18	150	184

To shew the near Agreement of the Pulses from Observation with the Pulses by the Theory, I have added this Table: Which contains in the first Column, the mean Ages of growing Bodies when they arrive at the Lengths in Inches standing  
over

over against them in the second Column; in the third Column, the mean Numbers of Pulses in a Minute in the Morning before Breakfast when the Bodies were sitting; and in the fourth Column, the Numbers of Pulses in a Minute supposing them to be inversly as the bi-quadrate Roots of the Cubes of the Lengths of the Bodies, and making 65 the first Number in the third Column found from Observation, the first Number in this. In making this Table, I neglected Fractions which were not near an Unit, and put an Unit instead of those which were.

It is to be observed, that the Number of Pulses from Observation of a Child newly born, falls considerably short of the Number of Pulses by the Theory. The Pulse of a Child newly born can scarcely be perceived. I have often try'd to  
feel



feel it and count its Numbers, but never succeeded: Once I reckon'd 150 Beats or more in a Minute in a Child seven or eight Days old. And therefore, though I have made 150 the mean Number, yet I cannot say, that it is the true mean Number; but supposing it to be so, its falling so much short of the Theory, may in some measure be accounted for from the Nature of that Cause which disposes Infants to sleep almost perpetually; which Cause by weakening the vibrating Motion of the *Æther* in the Nerves and Membranes of the Heart, must necessarily make the Pulse slower than it otherwise would be.

*Cor. 1.* The Velocities of the Blood in the corresponding Blood-Vessels of Bodies which are situated alike with respect to the Horizon, and whose Hearts are free from the  
the

the Influences of all disturbing Causes, are in Ratios compounded of the Ratios of the Lengths of the Bodies and the Ratios of the Numbers of their Pulses in a given Time: For in this Case, the Magnitudes of the Quantities of Blood thrown out of the Ventricles of their Hearts in one Systole, are as the Capacities of corresponding Blood-Vessels, that is,  $K. k :: D^2 L. d^2 l$ ; and therefore,  $V. v :: LP. lp$ .

*Cor. 2.* The Velocities of the Blood in the corresponding Blood-Vessels of Bodies of equal Lengths, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes, will be as the Numbers of their Pulses in a given Time, by the last *Corollary*; by which, when  $L = l$ ,  $V. v :: P. p$ . The same Proportion will obtain in

S one

one and the same Body at two different Times, if the Body at those Times be situated alike with respect to the Horizon, and its Heart be free from the Influences of all disturbing Causes: For the same System having different Magnitudes at different Times, may be considered as two Systems of equal Lengths.

*Cor. 3.* The Quantities of Blood, which in a given Time flow thro' the corresponding Blood-Vessels of Bodies situated alike with respect to the Horizon, when their Hearts are free from the Influences of all disturbing Causes, are in Ratios compounded of the Ratios of the Quantities of Blood contained in their Systems of Blood-Vessels and the Numbers of their Pulses in a given Time. For the Quantities of Blood which flow through corresponding Vessels in a given Time, are as the Squares of the Diameters of the Vessels



fels and the Velocities of the Blood flowing through them taken together, that is, as  $D^2V$  and  $d^2v$ ; But

$V. v :: \frac{KP}{D^2} \cdot \frac{kp}{d^2}$ , by this *Proposition*:

And  $K. k :: Q. q$ , the Density of the Blood being given; and therefore, the Quantities of Blood which flow through corresponding Blood-Vessels in a given Time, will be as  $\frac{D^2 QP}{D^2}$  and  $\frac{d^2 qp}{d^2}$ , that is, as  $Qp$  and  $qp$ .

The Quantities of Blood of a tall strong Man and of a Child newly born, are as the Numbers 16 and 1; and the Number of the Man's Pulses in a Minute in the Morning, when he is sitting, is 65 by the foregoing Table; and if the Number of the Child's Pulses in a Minute be 150, as it is there put down; the Quantities of Blood flowing through the Lungs of the Man and of the Child in a given

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Time,

Time, will be as the Numbers 104 and 15. According to *Tabor*, each Ventricle of the Heart of the Man can contain 1500 Grains of Blood; and consequently, when the Heart is not influenced by disturbing Causes, will throw out 5850000 Grains in an Hour: And each Ventricle of the Heart of the Child will throw out 843750 Grains in the same Time. Therefore, about 835 and 120 *Averdupois* Pounds of Blood will pass through the Lungs of the Man and of the Child in an Hour.

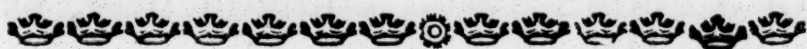
If the Quantities of Blood of strong well-proportioned Bodies be  $\frac{1}{12}$  part of their Weights, (as they are according to *Glisson* and *Tabor*) and if the Weights of a tall strong well-proportioned Man and a strong well-proportioned Child newly born, be 168 and 10 $\frac{1}{2}$  *Averdupois* Pounds; the whole Quantities of their Blood will be 14 Pounds and  $\frac{2}{3}$  of

of a Pound: And consequently, as much Blood as is contained in the Body, will flow  $59\frac{1}{2}$  times through the Lungs of the Man, and 137 times through the Lungs of the Child, in an Hour.

*Cor. 4.* If Bodies be situated alike with respect to the Horizon, and their Hearts be free from the Influences of all disturbing Causes; the Quantities of Blood which flow through their Lungs or other corresponding Parts in a given Time in Proportion to the whole Quantities of Blood contained in their Bodies, will be as the Numbers of their Pulses in a given Time: For the Quantities of Blood which flow through corresponding Blood-Vessels in a given Time, are as  $QP$  and  $qp$ , by the last *Corollary*; but  $\frac{QP}{Q}$  and  $\frac{qp}{q}$ , are as  $P$  and  $p$ .

Pro-





## Proposition XV.

**I**F Bodies be situated alike with respect to the Horizon; the Diameters of corresponding Blood-Vessels will be in the subquintuplicate Ratios of the Squares of the Products made by the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole and the Numbers of their Pulses in a given Time, that is,  $D. d :: \overline{K P^2} . \overline{k p^2}$ : The Velocities in corresponding Vessels will be in the subquintuplicate Ratios of those Products, that is,  $V. v :: \overline{K P^{\frac{1}{5}}} . \overline{k p^{\frac{1}{5}}}$ : And the Forces of their Hearts will be in Ratios compounded of the subquintuplicate Ratios of the Biquadrates of the same Products and of the simple Ratios of the Lengths of the Bodies, that is,  $F. f :: \overline{K P^{\frac{4}{5}}} \times L. \overline{k p^{\frac{4}{5}}} \times l$ .

For

For the Forces of the Hearts of Bodies situated alike with respect to the Horizon, are as the Capacities of corresponding Blood-Vessels, by the Proof of the 12th Proposition, that is,  $F. f :: D^2 L. d^2 l$ : The same Forces are in Ratios compounded of the duplicate Ratios of the Velocities and of the simple Ratios of the Diameters and Lengths of the Bodies, by the 4th Corollary of the 4th Proposition, that is,  $F. f :: V^2 D L. v^2 d l$ : But by the 14th Proposition,  $V^2. v^2. \frac{\overline{K P^2}}{D^4}. \frac{\overline{k p^2}}{d^4}$ ; and therefore,  $F. f :: \frac{\overline{K P^2} \times L}{D^3}. \frac{\overline{k p^2} \times l}{d^3}$ : And comparing this Proportion of the Forces with the first, we shall have  $D^2 L. d^2 l :: \frac{\overline{K P^2} \times L}{D^3}. \frac{\overline{k p^2} \times l}{d^3}$ ; whence  $D. d :: \overline{K P^2}^{\frac{2}{3}}. \overline{k p^2}^{\frac{2}{3}}$ .

Ex-

Extracting the Square Root of the last Analogy,  $\sqrt{D} . \sqrt{d} :: \overline{K P^{\frac{1}{2}}} . \overline{k p^{\frac{1}{2}}}$ : But  $V . v :: \sqrt{D} . \sqrt{d}$ , by the *12th Proposition*; and therefore,  $V . v :: \overline{K P^{\frac{1}{2}}} . \overline{k p^{\frac{1}{2}}}$ .

And squaring the same Analogy,  $D^2 . d^2 :: \overline{K P^{\frac{4}{2}}} . \overline{k p^{\frac{4}{2}}}$ : But  $F . f :: D^2 L . d^2 l$ ; and therefore,  $F . f :: \overline{K P^{\frac{4}{2}}} \times L . \overline{k p^{\frac{4}{2}}} \times l$ .

*Cor. 1.* If two Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon; the Forces of the Hearts of the two Bodies, or of the Heart of the same Body at the two Times, will be in Ratios compounded of the subquintuplicate Ratios of the Biquadrates of the Products made by the Magnitudes of the Quantities of Blood thrown out in one Systole and the Num-



Numbers of Pulses in a given Time;

If  $L=l$ ; then will  $F.f::\overline{K}P^{\frac{4}{3}}.\overline{k}p^{\frac{4}{3}}.$

*Cor. 2.* If two Bodies of equal Lengths, or one and the same Body at two different Times, be situated alike with respect to the Horizon; and if the Heart of the two Bodies, or the Heart of the same Body at those Times, throw out in one Systole Quantities of Blood whose Magnitudes are equal, that is, if  $L=l$ , and  $K=k$ : Then,  $D.d::P^{\frac{2}{3}}.p^{\frac{2}{3}},$  and  $V.v::P^{\frac{1}{3}}.p^{\frac{1}{3}},$  and  $F.f::P^{\frac{4}{3}}.p^{\frac{4}{3}}.$

### *Examples.*

*Exam. 1.* If from some Cause the Pulse of the same Body become twice as quick as it is in the Morning when the Body is sitting, and the Heart is free from the Influences

ces of all disturbing Causes ; and if it become greater than under the Circumstances now mentioned, from the Heart throwing out its usual Magnitude of Blood in half the Time, that is, if  $P. p :: 2. 1$  ; and  $K = k$  : Then, by the second *Corollary* of this *Proposition*,  $D$  and  $d$  will be as the Numbers 13195 and 10000,  $V$  and  $v$  as the Numbers 11487 and 10000, and  $F$  and  $f$  as the Numbers 17411 and 10000. This seems to be pretty much the Case of a grown Body heated by an *ardent Fever*, or *violent Exercise*, in which the Pulse is greater than ordinarily, and beats about twice as fast as it does in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes ; and therefore, in a Body so heated, the Diameters of the Blood-Vessels will be increased in the Proportion of 13195 to 10000, the Velocity of  
the

the Blood in the Proportion of 11487 to 10000, and the Force of the Heart in the Proportion of 17411 to 10000.

*Exam. 2.* If the Pulse of the same Body be quicker at one Time than at another, in the Proportion of 80 to 70; and if it be greater from the Heart throwing out its usual Magnitude of Blood in a less Time, that is, if  $P. p :: 80. 70$ ; and  $K=k$ : Then, by the second *Corollary* of this *Proposition*, D and d will be as the Numbers 10549 and 10000, V and v as the Numbers 10270 and 10000, and F and f as the Numbers 11127 and 10000. The Pulse is quicker and greater in the *Afternoon*, than it is in the *Morning*; and from many Observations, taking one Hour with another of those two Times, it is quicker in grown Bodies one with another, in the Proportion of about 80 to 70: And

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there-



Morning.												Afternoon.												Mean
Hours						Pulses of A.						Pulses of B.						Mean						
8	9	10	11	12	1	2						3	4	5	6	7	8	9	10	11				
65	67	70	73	71	69	70	70	77	77	77	77	77	77	77	76	76	74	74	74	76	76			
66	71	72	68	69	67	67	68 <sub>1</sub>	75	81	84	81	79	77	78	78	78	79	78	79	78				

therefore, the Diameters of the Blood-Vessels of the same Body will be greater than in the Morning, taking one Hour with another, in the Proportion of 10549 to 10000, the Velocities in the Vessels will be greater in the Proportion of 10270 to 10000, and the Force of the Heart will be greater in the Proportion of 11127 to 10000.

I have added this Table, to shew the Tenour of the Pulse at different Hours of the Day; it contains the Numbers of Pulses in a Minute of two health-

ful Men A and B, when sitting, at the

the several Hours from eight a Clock in the Morning to eleven at Night. These Numbers, are Means drawn from a large Number of Observations ; those of A, from the Observations of twelve Weeks ; and those of B, from the Observations of three Weeks. A eat his Breakfast between nine and ten, B his before nine ; they both dined together at two, at which Meal B eat more plentifully than A ; and they eat little or no Supper.

From this Table it appears, that the Pulse is slower in the Morning, than at any other Time of the Day ; that it grows something quicker before Breakfast, and a little more so after it ; that it grows slower again before Dinner, and quicker immediately after Dinner ; and that the Quickness acquired by this Meal, continues for about three or four Hours, and then abates a little ; and

con-

continues in that State, without any considerable Change, in Bodies which eat and drink little at Night, till they go to Rest.

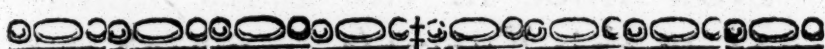
*Exam. 3.* If from some Cause the Pulse of the same Body becomes quicker than it is in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, in the Proportion of 2 to 1; and if it becomes smaller, from the Heart throwing out in each Systole but a fourth part of the Blood which it throws out in the Morning under the Circumstances now mentioned, that is, if  $P. p :: 2. 1$ ; and  $K. k :: 1. 4$ : Then, by this *Proposition* and its first *Corollary*, D and d will be as the Numbers 7578 and 10000, V and v as the Numbers 8705 and 10000, and F and f as the Numbers 5743 and 10000. If this be nearly the Case of a grown Body in a *malignant Fever*,



*Fever*, the *Cold Fit of an Ague*, *Convulsions*, and some other Diseases; then, when the Body is sitting, the Diameters of corresponding Blood-Vessels will be lessened in the Proportion of 7578 to 10000, the Velocities in the Vessels will be lessened in the Proportion of 8705 to 10000, and the Force of the Heart will be lessened in the Proportion of 5743 to 10000.

Now since in the Cases mentioned in this *Example*, in which the Force of the Heart is lessened, the Skin is much paler and colder than in a natural and healthful State; and is extremely pale and cold in *dead Bodies*, in which the Force of the Heart is wholly destroyed: And on the contrary, since in the Cases mentioned in the *first Example*, in which the Force of the Heart is increased, the Skin is much redder and warmer than in a natural and health-

healthful State: We may from the Colour and Warmth of the Skin, most certainly judge of the Force of the Heart; and at the same time see, how as that Force gradually lessens, the Compass of the Blood's Motion gradually contracts; till at last, that Force wholly ceasing to act, the Motion wholly ceases, even in the largest Vessels nearest to the Heart.



Proposition XVI.

***I**f the Catamenia flow through Foramina in the Sides of the Blood-Vessels of the Uterus into its Cavity, if there be the same Number of corresponding Foramina in the Sides of corresponding Blood-Vessels in all healthful Bodies, if this Discharge continues a given Number of Days, and during that Time of its Continuance*

*ance Bodies be situated alike with respect to the Horizon; the Quantities of one Discharge of grown Bodies will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels, that is, putting C, c for the Quantities of one Discharge of two grown Bodies,  $C. c :: D^2 \vee D. d^2 \vee d$ .*

For the whole Quantities of Blood discharged by two healthful Bodies in a given Number of Days, will be as the Quantities discharged by any two corresponding *Foramina* in that Time; and the Quantities discharged by two corresponding *Foramina*, will be as the Squares of their Diameters and the Velocities wherewith the Blood flows thro' them, taken together: But the Diameters of two corresponding *Foramina* are as the Diameters of two corresponding Blood-Vessels; and

U the



the Velocities wherewith the Blood flows through the *Foramina*, are as the Velocities wherewith the Blood flows through those Vessels: And therefore, the Quantities discharged by two corresponding *Foramina*, will be as the Squares of the Diameters of two corresponding Blood-Vessels and the Velocities wherewith the Blood flows through them, taken together, that is, as  $D^2\sqrt{D}$  and  $d^2\sqrt{d}$ ; for by *Prop.* 12.  $V.v::\sqrt{D}.\sqrt{d}$ : And the whole Quantities of one Discharge of two healthful Bodies situated alike with respect to the Horizon, which are as the Quantities discharged by two corresponding *Foramina*, will be as  $D^2\sqrt{D}$  and  $d^2\sqrt{d}$ , that is,  $C.c::D^2\sqrt{D}.d^2\sqrt{d}$ .

*Cor.* 1. Since this Discharge usually begins in these Countries between the Ages of 14 and 16 Years, at which Ages Bodies are not come  
to

to their full Growth; it is evident, if this *Proposition* be true, that this Discharge will continually increase from its first Appearance till that Time; for both the *Foramina* grow larger, and the Velocity of the Blood increases, while Bodies are growing; and it will likewise increase, from some of the *Foramina* being naturally smaller than others, on which Account they will necessarily, not all at once, but successively, become large enough to let the Blood pass through them.

*Cor. 2.* If this *Proposition* be true, this Discharge will begin soonest and be greatest in Bodies which have the largest Blood-Vessels: For it will begin when the *Foramina* are grown large enough to let the red Parts of the Blood (which are its largest Parts) pass thro' them; but they will be soonest large enough to do this, in Bodies which have the largest

Blood-Vessels: And the Quantities of a Discharge will be greatest, because the *Foramina* are largest, and the Velocity of the Blood is greatest, in such Bodies.

*Cor. 3.* The Quantities of this Discharge in grown well-proportioned Bodies of different Lengths, and its mean Quantities in all grown Bodies of different Lengths taking those of each Length one with another, will, if this *Proposition* be true, be in Ratios compounded of the simple and the subquadruplicate Ratios of the Lengths of the Bodies; the Diameters of corresponding Blood-Vessels in these Cases, being in the subduplicate Ratios of those Lengths, by *Cor. 4. Prop. 12.*

*Cor. 4.* Hence it appears, that this Discharge will be increased by all Things which swell the Blood-Vessels; and on the contrary, lessened



fened by all Things which contract them : And therefore, it will be increased by whatever increases the Power of the Heart, and heats the Blood; and lessened by whatever lessens the Power of the Heart, and cools the Blood; for the Blood-Vessels swell or contract, as the Force of the Heart is increased or lessened by Heat or Cold, or other Causes.

*Cor. 5.* Hence it appears, that a Discharge must continue till the Blood-Vessels and *Foramina* are so far contracted by the Loss of Blood, that the *Foramina* are too small to let the red Parts of the Blood pass thro' them; and then it will cease for that Time, and not return again till the lost Blood be regained, and the Blood-Vessels and *Foramina* be enlarged to the Dimensions they were of at the coming on of the preceding Discharge; and then  
another

another Discharge will begin, continue the same Time, and go off as that did. Thus this Discharge happens once a Month, in which Time the lost Blood is regained; continues in these Countries till about the Age of 50; and then wholly ceases, from the *Foramina* being too small to let the Blood pass thro' them. And the *Foramina* become too small from a Rigidity in the Blood-Vessels, which hinders them from being dilated by the Blood as usually: For it appears both from Anatomy and common Experience, that the Blood-Vessels and other solid Parts become more rigid, as Bodies advance in Years.



Proposition XVII.

***I**F Q the Quantity of Blood contained in a healthful Body before*

fore a Discharge of the Catamenia begins, and  $P$  and  $p$  the Numbers of Pulses in a Minute a little before and after the Discharge when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, be all known;  $C$  the Quantity of the Discharge will be known, for it will be equal to  $Q \times \frac{P^4 - p^4}{P^4}$ .

For the Heart being supposed to be free from the Influences of all disturbing Causes before the Discharge and after it, the Heat and Density of the Blood will both of them be the same before and after; and therefore, if  $q$  denote the Quantity of Blood contained in the Body after the Discharge is over,  $V. v :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$ , by *Cor. 3. Prop. 12*; and  $V. v :: P. p$ , by *Cor. 2. Prop. 14*; and from these two Analogies,  $Q^{\frac{1}{4}}. q^{\frac{1}{4}} :: P.$



P. p; and Q—q.  $Q :: P^4 - p^4 . P^4 :$   
 But  $Q - q = C$ ; and consequently,  
 $C.Q :: P^4 - p^4 . P^4$ ; and  $C = \frac{Q \times P^4 - p^4}{P^4}$ .

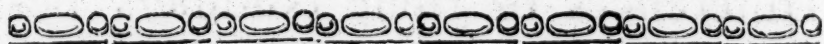
For *Example*, If the Quantity of Blood contained in the Body at the Beginning of the Discharge be 11 *Averdupois* Pounds, and the Pulses in a Minute before and after the Discharge when the Body is sitting and its Heart is perfectly free from the Influences of all disturbing Causes be 74 and 73; the Quantity of the Discharge will be above 9 Ounces: If the Quantity of Blood be 11 Pounds, and the Pulses in a Minute before and after be 74 and 72; the Quantity of the Discharge will be above 18 Ounces.

I have found from Observation, that the Pulse is quicker before the Discharge than after it. The Pulse of a well-proportioned Body 64  
 Inches

Inches high, in which this Discharge was very small, was observed at every Hour of the Day for 8 Months together; and the Pulse of another Body six Inches shorter, in which this Discharge was very great, was observed at every Hour of the Day for a Month; and the mean Numbers of Pulses in a Minute, taken from all the Observations made on the two Bodies in the Week before and Week after the Discharge, were 74 and 72 in the taller Body, and  $79\frac{1}{2}$  and 75 in the shorter. The Differences of these Numbers before and after the Discharge, are too great for the Quantity of the Discharge in these Climates; which I believe does not ordinarily exceed 12 Ounces in tall and well-proportioned Bodies. And if from more Observations of the Pulse of perfectly healthful Bodies which have this Discharge in due Quantities it

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shall be found, that the Differences of its Numbers before and after the Discharge make it greater than it really is in these Climates; then the Quantity of a Discharge cannot be determined by this *Proposition*, which supposes the Heart before and after the Discharge to be free from the Influences of all disturbing Causes: But it may be determined by the next *Proposition*, when from Experiments and Observations all the Terms used in it shall be known.



### Proposition XVIII.

**I**F *Q* the Quantity of Blood contained in the Body at the Beginning of a Discharge of the Catamenia, *P* and *p* the Numbers of Pulses in a Minute when the Body is sitting, *K* and *k* the Magnitudes of the Quantities of Blood thrown out of the Heart  
in



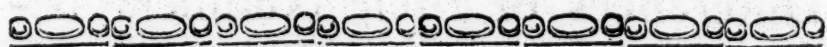
*in one Systole, and  $\Delta$  and  $\delta$  the Densities of the Blood, before and after the Discharge, be all known; the Quantity of a Discharge will be known,*

$$\text{for } C = Q \times \frac{\overline{KP}^{\frac{4}{5}} \times \Delta - \overline{kp}^{\frac{4}{5}} \times \delta}{\overline{KP}^{\frac{4}{5}} \times \Delta}.$$

For the Capacities of one and the same Blood-Vessel before and after the Discharge, are as the Squares of its Diameters; which Squares when the Body is sitting are as  $\overline{KP}^{\frac{4}{5}}$  and  $\overline{kp}^{\frac{4}{5}}$  by the 15th Proposition: And the Quantities of Blood contained in one and the same Blood-Vessel at those Times are as the Squares of its Diameters and the Densities of the Blood taken together: But the Quantities of Blood contained in the whole Body, are as the Quantities of Blood contained in one and the same Blood-Vessel when the

X 2                      Body

shall be found, that the Differences of its Numbers before and after the Discharge make it greater than it really is in these Climates; then the Quantity of a Discharge cannot be determined by this *Proposition*, which supposes the Heart before and after the Discharge to be free from the Influences of all disturbing Causes: But it may be determined by the next *Proposition*, when from Experiments and Observations all the Terms used in it shall be known.



### Proposition XVIII.

**I**F *Q* the Quantity of Blood contained in the Body at the Beginning of a Discharge of the Catamenia, *P* and *p* the Numbers of Pulses in a Minute when the Body is sitting, *K* and *k* the Magnitudes of the Quantities of Blood thrown out of the Heart  
in

*in one Systole, and  $\Delta$  and  $s$  the Densities of the Blood, before and after the Discharge, be all known; the Quantity of a Discharge will be known,*

$$\text{for } C = Q \times \frac{\overline{KP}^{\frac{4}{5}} \times \Delta - \overline{kp}^{\frac{4}{5}} \times s}{\overline{KP}^{\frac{4}{5}} \times \Delta}.$$

For the Capacities of one and the same Blood-Vessel before and after the Discharge, are as the Squares of its Diameters; which Squares when the Body is fitting are as  $\overline{KP}^{\frac{4}{5}}$  and  $\overline{kp}^{\frac{4}{5}}$  by the 15th Proposition: And the Quantities of Blood contained in one and the same Blood-Vessel at those Times are as the Squares of its Diameters and the Densities of the Blood taken together: But the Quantities of Blood contained in the whole Body, are as the Quantities of Blood contained in one and the same Blood-Vessel when the

X 2                      Body



Body is fitting: And therefore, the Quantities of Blood contained in the whole Body before and after the Discharge, are as  $\overline{KP^{\frac{4}{5}}} \times \Delta$  and  $\overline{kp^{\frac{4}{5}}} \times \delta$ , that is  $Q. q :: \overline{KP^{\frac{4}{5}}} \times \Delta. \overline{kp^{\frac{4}{5}}} \times \delta$ ; whence

$$Q - q = C = Q \times \frac{\overline{KP^{\frac{4}{5}}} \times \Delta - \overline{kp^{\frac{4}{5}}} \times \delta}{\overline{KP^{\frac{4}{5}}} \times \Delta}.$$

*Cor. 1.* If the Degrees of Heat in the Blood, and consequently its Densities, before and after the Discharge, be equal; and if the Magnitudes of the Quantities thrown out in one Systole before and after be likewise equal, that is, if  $\Delta = \delta$ , and

$$K = k; \text{ then will } C = Q \times \frac{\overline{P^{\frac{4}{5}}} - \overline{p^{\frac{4}{5}}}}{\overline{P^{\frac{4}{5}}}}.$$

For *Example*, If the Quantity of Blood contained in the Body when the Discharge begins be 11 Pounds, and the Numbers of Pulses in a Minute

nute before and after the Discharge when the Body is sitting be 74 and 70; the Quantity of the Discharge will be above  $7\frac{1}{2}$  Ounces; and near 9 Ounces, if the Quantity of Blood in the Body when the Discharge begins be 12 Pounds. It is to be observed, that the Degrees of Heat in the Blood before and after the Discharge, may be known by a Thermometer truly adjusted: And by the Fulness of the Pulse we may judge of the Magnitudes of the Quantities of Blood thrown out in one Systole: And therefore, from Experiments and Observations carefully made by Persons who have an Opportunity of doing it, the Quantity of a Discharge may be nearly known by this *Proposition*.

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## Proposition XIX. Problem II.

**T**HE *Blood-Vessels of a particular Part of the Body being obstructed or opened, contracted or dilated; to determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Vessels of all the other Parts.*

*Case I.* If the Arterial Trunk of a Part be obstructed or contracted, so as either wholly or in some Degree to hinder the Blood from flowing through that Part; the Velocity will be increased in all the other Parts, and its Increase will be greater or less, *cæteris paribus*, as the Arterial Trunks of those Parts are nearer to or farther from the Trunk which is obstructed or contracted, by *Cor. Prop. 7.*

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The Blood-Vessels of the Part whose Artery is obstructed or contracted will contract and grow less, from a Destruction or Diminution of the Force of the Blood's Motion which before the Obstruction or Contraction of the Trunk kept those Vessels distended: And the Blood-Vessels of all the other Parts will swell and grow larger, by the Force of the augmented Motion of the Blood; and their Swelling and Enlargement will be greater or less, *cæteris paribus*, as they are nearer to or farther from the obstructed or contracted Trunk. Like Changes will be made in the Velocities of the Blood and Magnitudes of the Blood-Vessels of all the other Parts, if, instead of the Arterial Trunk of a Part, any of the Branches of that Part (whether Arteries or Veins) be obstructed or contracted; because such Obstruction or Contraction will  
lessen

lessen the Velocity in the Arterial Trunk, by *Cor. 2. Prop. 5*; and by Consequence, will produce like Changes in the Velocities and Magnitudes of the Vessels of the other Parts, as would be produced by a real Contraction of that Trunk. .

*Case II.* If the Arterial Trunk of a Part be opened or dilated, the Blood will flow faster into that Trunk and slower through all the other Parts of the Body than it did before; and the Diminution of Velocity in the other Parts will be greater or less, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened or dilated, by *Cor. Prop. 7*.

If the Trunk be opened, and the greatest part of the Blood which flows into it flow out of the Orifice; the Vessels of that Part will contract and grow less, from the  
Blood

Blood running out of them, and their not receiving their usual Supply to keep them distended. And the Vessels of all the other Parts will likewise be contracted, from a Diminution of the Velocity of the Blood in them; and their Contraction will be greater or less, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened; and they will undergo like Changes of Magnitude, when the Arterial Trunk is only dilated; tho' the Vessels of the Part supply'd by the dilated Trunk will all swell and grow larger, contrary to what happened to them when the Trunk was opened. Like Changes will be made in the Velocities and Magnitudes of the Vessels of other Parts, when instead of the Arterial Trunk, one or more of the Branches (whether Veins or Arteries) of a Part are opened or dilated. For a Dilatation or Opening

Y of



of any of the Branches will increase the Velocity in the Arterial Trunk, by *Cor. 1. Prop. 5* ; and by Consequence, will produce like Changes in the Velocities and Magnitudes of the Vessels of the other Parts as would be produced by a real Dilatation or Opening of the Arterial Trunk.

*Case 3.* If the Venal Trunk of a Part be obstructed or contracted, the Blood will thereby be either totally or in some measure hindered from flowing out of the Part ; on which Account, its Vessels will swell from the Blood flowing faster into than it flows out of them for some little Time till they can be no farther distended : After that, if less Blood flow into the Arterial Trunk of the Part than did before ; like Changes of Velocity and Magnitude will be produced in the Blood-Vessels

Vessels of all the other Parts, as were produced in them by the Obstruction or Contraction of the Arterial Trunk by the *first Case*.

*Case 4.* If the Venal Trunk of a Part be opened or dilated, the Blood will flow faster thro' the Part than it did before; because the Aperture or Dilatation either takes off or lessens the Resistance arising from the Blood which lies before it: The Velocity therefore will be increased in the Arterial Trunk, and it will be lessened in the Vessels of all the other Parts; and its Diminution in those Vessels, and the Contraction of their Magnitudes consequent thereon, will be greater or less, *cæteris paribus*, as the Vessels are nearer to or farther from the Part whose Vein is opened or dilated, by the *second Case*. The Vessels of the Part whose Venal Trunk is opened will

contract, notwithstanding the Velocity of the Blood in them is increased: For by the Aperture, the Resistance given by the Blood lying beyond it to the Motion of the Blood through the Part, will be taken off; and by Consequence, the Velocity of the Blood flowing through the Part will be increased: But this Increase of Velocity beginning in the Vein at the Place of Aperture, and thence successively running thro' the Venal and Arterial Branches, and at last ending in the Arterial Trunk, it is evident, that more Blood will in a given Time flow out of each of these Vessels, than flows in; and by Consequence, all these Vessels will be contracted; and the Contraction will first begin, where the Increase of Velocity first began, and successively go thro' the Vessels in the same Manner as that did.

*Cor.*



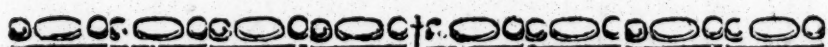
*Cor. 1.* Hence it appears, that if a Part be overloaded with Blood, it will be soonest emptied by opening the Vessels of the Part it self; and next, by opening the Vessels of the Parts which are nearest to it.

*Cor. 2.* If the Blood flow too fast into some one Part, from an Aper-  
ture or Dilatation of some of its Blood - Vessels; the preternatural Influx of Blood into this Part will be lessened by increasing the Motion of the Blood thro' the other Parts.

*Cor. 3.* If the Blood flow too slow into some one Part, from an Obstruction or Contraction of some of its Blood-Vessels; the Motion through this Part will be increased by contracting the Vessels and lessening the Motion thro' the other Parts.

*N. B.*

N. B. There may perhaps be some little Disturbances given to these Laws of Apertures and Obstructions, Dilatations and Contractions of the Blood-Vessels, from several Inosculations of Arteries with Arteries, and Veins with Veins ; but as these Disturbances cannot be accurately determined, so neither can they be considerable ; as appears from the Success of Practice grounded on these Laws.



Proposition XX. Problem III.

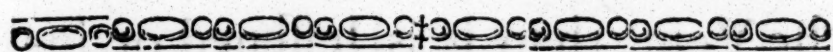
**T**O *determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Vessels in different Parts of the Body, when it is situated differently with respect to the Horizon.*

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The corresponding Arteries and Veins are every where contiguous ; and the Veins are larger than their corresponding Arteries, and consequently, contain a greater Quantity of Blood : On which Accounts, when the Force of Gravity in a Vein conspires with or opposes the Motion of the Blood through it, that Motion will be more increased or lessened by the Force of Gravity in the Vein, than it is lessened or increased by the same Force in the corresponding Artery ; and more or less Blood will by Virtue of this Force flow through the Vein, than will flow through the Artery in the same Time ; and therefore, if the Vein and Artery be the two Trunks of a Part ; more or less Blood will flow out of the Part than flows in, and the Blood-Vessels of the Part will be contracted or dilated. For Instance, in the Day when the Body



dy is erect, Gravity conspires with the Motion of the Blood from the Head, and opposes its Motion from the Legs; and in the Night, when the Body is horizontal, Gravity neither conspires with nor opposes the Motion from these Parts: And hence the Head will contain less, and the Legs more Blood, in the Day than in the Night.



Proposition XXI. Problem IV.

**T**O *determine the Influence and Power of the Soul over the Motion of the Heart.*

That the Soul has a very great Power over the Heart appears from the following Instances. A dying Man who had had little or no Pulse, and had been in cold clammy Sweats for several Hours, was by  
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an Accident exceedingly alarmed, and thrown into the greatest Disturbance of Mind; upon which his Heart and Blood gradually recovered their Motions to a considerable Degree, and kept them above an Hour, till his Mind grew calm and easy; and then they lost them again, and he died in less than half an Hour. A strong Extension of the Legs and Arms by the Power of the Will, has quickened the Pulse 20 Beats in a Minute, and at the same Time made it so low, that it could scarcely be felt. The Pulses in a Minute of a Man lying, sitting, standing, walking at the Rate of two Miles in an Hour, at the Rate of four Miles in an Hour, and running as fast as he could, were 64, 68, 78, 100, 140, and 150 or more. When a Body stands up, the Pulse begins to grow quicker the very Instant the Body begins to rise, or

Z the

the Soul begins to exercise the Power which raises it; and when a Body moves, it grows still quicker; and the Soul exercises more Force to move the Body, in Proportion to the Quickness of the Motion: When a Body first stands up and begins to move, the Pulse is smaller than it was before; but grows greater by Degrees, as the Body grows warm by the Motion. A Fit of Laughing has quickened the Pulse 25 Beats in a Minute: And breathing voluntarily three or four Times faster than usually, has quickened it 13 or 14 Beats: The Pulse is quickened by coughing, swallowing, reading loud, or by any Motion that is performed by the Power of the Soul. From hence it appears, that the Motion of the Heart is changed mediately or immediately, by every Change made in the Affections, Activity or Power of the Soul.

*Of*



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*Of Respiration.*

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## Proposition XXII.

*IF a Wind blow uniformly, and a heated Body be placed in it to cool; the Time of its cooling will be greater or less, as the Quantity of Matter in the Body, or its Degree of Heat at the Time of its being first placed in the Wind, or the Degree of Heat in the Wind, is greater or less; or as the Surface of the Body is less or greater.*

For if the Degree of Heat in the Body at the Time of its being first placed in the Wind, and the Degree of Heat in the Wind, be both given; the Time of its cooling will be as the Quantity of Heat in the Body in Proportion to the Measure

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according to which it is cooled : But the Degree of Heat in the Body being given, its Quantity of Heat will be as its Quantity of Matter ; and the Surface of the Body is the Measure according to which it is cooled : And therefore, the Time of cooling will be as the Quantity of Matter in the Body in Proportion to its Surface ; and by Consequence, will be greater or less, as the Quantity of Matter is greater or less, or as the Surface is less or greater : If the Body, and Degree of Heat in the Wind, be both given ; the Time of its cooling will be greater or less, as the Degree of Heat in the Body when first placed in the Wind is greater or less. From what Sir *Isaac Newton* has proved in his *Scale of the Degrees of Heat*, it is evident, that the Time of the Body's cooling will not be proportional to its Heat when first placed in the Wind :  
For

For if one and the same Body has different Degrees of Heat, the Times of its cooling will be in Arithmetick Proportion, when the Degrees of Heat are in Geometrick Progression; whence the Time of cooling in Proportion to the Heat, will for the most part be greater when the Heat is less; and therefore, the Time of cooling will not be proportional to the Degree of Heat in the Body when first placed in the Wind: And yet notwithstanding this, it will ever be greater when the Heat is greater, and less when it is less; which is all that is affirmed in the *Proposition*. If the Body, and its Degree of Heat when first placed in the Wind, be both given; the Time of cooling will be greater or less, as the Wind is warmer or colder, that is, as the Degree of Heat in the Wind is less or greater: And therefore, the *Proposition* is true.

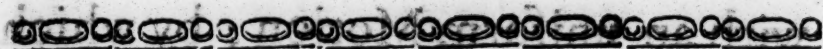
*Cor.*



*Cor. 1.* If a Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly, and the Degree of Heat in the Wind be given; the Time of its cooling, will be as a given Side and the Density of the Body taken together, as is evident from the Proof of this *Proposition*. If the Body be a Cube, the Time of its cooling will be as the Side and Density of the Cube; and if a Globe, as the Diameter and Density of the Globe; taken together.

*Cor. 2.* If a homogeneous Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly whose Heat is given; the Time of its cooling will be as a given Side of the Body. If the Body be a Cube, the Time of its cooling will be as the Side of the Cube; and if a Globe, as its Diameter.

Pro-



## Proposition XXIII.

**I**F a Wind blow uniformly, and a heated Body be placed in it to cool; the Heat which the Body when first placed in the Wind will communicate to the Air, and consequently lose, in a very short given Time, will be as the Heat and Surface of the Body taken together directly, and the Heat of the Air inversely. If  $S$  denote the Surface of the Body,  $H$  its Degree of Heat when placed in the Wind, and  $h$  the Heat that is communicated to the Air and lost in the Body in a very short given Time; I say, that  $h$  will be as  $\frac{SH}{A}$ .

For the Wind blowing uniformly, the Air heated by the Body will be always carried off by the Wind,  
and

and other Air succeed into its Place with an uniform Motion ; by which Means, equal Parts of Air will be heated by the heated Body in equal Times, and conceive a Heat proportional to the Heat of the Body ; and consequently, one and the same heated Body, placed in a Wind blowing uniformly whose Degree of Heat is given, will when first placed in the Wind communicate to the Air, and consequently lose, in a short given Time, a Heat which is proportional to the Heat of the Body : If the Body be different, but its Degree of Heat, and the Degree of Heat in the Wind, be both given ; the Body will communicate to the Air, and consequently lose, in a very short given Time, a Heat which is proportional to the Surface of the Body : And if both the Body and its Degree of Heat be different, it will communicate to the Air, and consequently,



ly lose, in a very short given Time, a Heat which is proportional to the Coldness of the Wind; which Coldness is inversely as its Degree of Heat: And therefore, the Heat communicated to the Air, and lost by a Body heated and placed in a Wind blowing uniformly, will be as the Heat and Surface of the Body taken together directly; and the Heat of the Wind inversely, that is,  $h$  will be as  $\frac{SH}{A}$ .

*Cor. 1.* If the Heat of the Wind be given; the Heat which is communicated to the Air, and lost in the Body, in a given Time, will be as the Surface of the Body, and its Degree of Heat when first exposed to the Wind, taken together. If  $A$  be given,  $h$  will be as  $SH$ .

*Cor. 2.* If the Degree of Heat in the Body, when first exposed to the  
 $A$  a Wind,

Wind, be given ; the Heat communicated to the Air, and lost in the Body, in a given Time, will be as the Surface of the Body directly ; and the Degree of Heat in the Wind inversely. If  $H$  be given,  $h$  will be as  $\frac{S}{A}$ .

*Cor. 3.* If the Surface of the Body be given; the Heat which is communicated to the Air, and lost in the Body, in a given Time, will be as the Heat of the Body, when first exposed to the Wind, directly ; and as the Heat of the Wind inversely. If  $S$  be given,  $h$  will be as  $\frac{H}{A}$ .

*Cor. 4.* If the Degree of Heat in one and the same Body, when first exposed to the Wind, be given ; the Heat which it will communicate to the Air, and consequently lose, in a very short given Time, will be  
inversely

inversly as the Heat ; or directly as the Coldness of the Wind. If S and H be given, h will be as  $\frac{I}{A}$ .



### Proposition XXIV.

**T**HE *Life of Animals is preserved by acid Parts of the Air, mixing with the Blood in the Lungs: Which Parts dissolve or attenuate the Blood, and preserve its Heat ; and by both these, keep up the Motion of the Heart.*

I shall prove the Truth of this *Proposition*, from a Series of Experiments and Observations.

*First* then, Animals die, when they are deprived of Air by stopping the Wind-Pipe, or putting them in an Air Pump and drawing



out the Air. And they likewise die soon, in a small Quantity of Air so closely confined, as to have no Communication with the rest of the Atmosphere: Small Birds cannot live above three or four Hours in a Quart of such Air; and a Gallon of Air included in a Bladder, and by a Pipe reciprocally inspired and expired by the Lungs of a Man, will become unfit to preserve Life, in little more than one Minute of Time.

Hence it appears, that Air is necessary to preserve the Life of Animals: And likewise, that a constant Supply of fresh Air is necessary to that End.

*Secondly,* A Candle goes out, glowing Coals and red-hot Iron cease to shine, and Animals die, in the Air-Pump on drawing out the Air. A Candle goes out, glowing  
Coals

Coals and red-hot Iron cease to shine, and Animals die, in a small Quantity of Air so closely confined, as to have no Communication with the rest of the Atmosphere. Animals die in Air rendered effete by burning Coals or Candles in it till they are extinguished, and glowing Coals or Candles are extinguished in Air rendered effete by Animals breathing in it till they die. *Hook* found, that if Air rendered effete be blown on live Coals, it produces no other Effect, than to blow off the Ashes and put out the Fire; and that the more you blow, the more dead is the Light, and the sooner is the Fire quite extinct; in-somuch that in a very little Time, the Coals become perfectly black without emitting the least Glimpse of Light or Shining: At which Time, if one Blast of fresh Air be blown upon those seemingly dead, extinct, and  
black

black Coals, they all begin to glow, burn, and shine afresh, as if they had not been at all extinct; and the more fresh Air is blown upon them, the more they shine, and the sooner are they burnt out and consumed: And Animals put into such effete Air soon die, tho' for some Time they breath, and move their Lungs as before. The Medium found in Damps, is present Death to those who breath it; and in an Instant, extinguishes the brightest Flame, the Shining of glowing Coals, or red-hot Iron, when put into it. Common Air, by passing thro' red-hot Brass, red-hot Iron, red-hot Charcoal, or the Flame of Spirit of Wine, becomes unfit to preserve Life, and the Shining of Fire and Flame.

Hence it appears, that fresh Air preserves Life in Animals by the very same Power, or by the Operation



ration of the very same Parts, whereby it preserves Fire and Flame in sulphureous and unctuous Substances, when once they are kindled.

*Thirdly*, If two Parts of compound Spirit of Nitre be poured on one Part of Oil of Cloves or Caraway Seeds, or of any ponderous Oil of Vegetable or Animal Substances, or Oil of Turpentine thickened with a little Balsam of Sulphur; the Liquors grow so very hot in mixing, as presently to send up a burning Flame: If a Drachm of the same compound Spirit be poured upon half a Drachm of Oil of Caraway Seeds, even *in vacuo*, the Mixture immediately makes a Flash like Gunpowder: And well-rectified Spirit of Wine poured on the same compound Spirit flashes. Common Sulphur and Nitre powdered, mixed together, and kindled, will continue

tinue to burn under Water, or *in vacuo*, as well as in the open Air.

Now since Air is necessary to preserve common Fire and Flame in sulphureous and unctuous Substances, when once they are kindled; and it appears by these Experiments, that Fire and Flame may both be produced and preserved in sulphureous and unctuous Substances, by acid Particles even without Air; it follows, that Air preserves Fire and Flame by means of acid Particles: And since it preserves the Life of Animals, by the Operation of the very same Particles whereby it preserves Fire and Flame; it likewise follows, that it preserves the Life of Animals by its acid Particles.

\* *Fourthly*, The Venal Blood is of a deep purple Colour and the Arterial Blood of a bright red, in all Parts of the Body except the Lungs; and

and in them the Blood is of a dark purple Colour in the Pulmonary Artery, and of a bright red in the Pulmonary Vein. Hence it follows, that the Blood changes its deep purple Colour into a bright red, in the communicant Branches of the Pulmonary Artery and Vein which are spread on the Vesicles ; and that it changes its bright red into a deep purple Colour, in the communicant Branches of the Arteries and Veins of other Parts. If Blood be drawn out of a Vein, its upper Surface, which is contiguous to the Air, will acquire the same bright red Colour which the Blood acquires in the Lungs ; and if this red Surface be cut off with a sharp Knife, the blackish Surface of the remaining Blood, being now touched and acted upon by the Air in the same Manner as the first, will acquire the same Colour as that did ; and the same

B b

Change



Change of Colour will be made in the Bottom of the Cake, if it be turned upwards in the Cup, and exposed to the Air; and if Blood just drawn be stirred and agitated, till the Air be intimately mixed with it throughout, its whole Substance will soon acquire the bright red Colour of Arterial Blood. If the Wind-Pipe be stopped with a Cork, and some Time after the Operation (when the Air which is shut up in the Lungs is made effete, that is, deprived of its acid Parts) Blood be drawn from the Cervical Artery, it will have the same dark purple Colour as Venal Blood.

Now since from these Experiments; the Air must touch Venal Blood drawn out of the Body to change its deep purple Colour into a bright red, and the acid Parts of the Air cause the same Change of Colour in the Blood in  
the

the Lungs ; it will follow, that there must be a like Contact of these acid Parts with the Blood in the Lungs. And since I have shewn, that Air preserves the Life of Animals by its acid Parts ; it will likewise follow, that the Life of Animals is preserved by acid Parts of the Air mixing with the Blood in the Lungs.

*Fifthly*, The bright red Colour acquired by the Blood in the Lungs, from its Purity and Intenseness, is the Red of the second Order of Colours in the Table of Sir *Isaac Newton's Opticks*, p. 206 : But the blackish or deep purple Colour of Venal Blood turns into this bright Red, without passing through the Colours of Blue, Green, Yellow, and Orange ; and therefore, must arise from the Indigo and Purple of the third Order, and not from the Indigo and Violet of the second : And

consequently by that Table, the tinging Corpuscles of the Blood are lessened in the Lungs.

Hence it appears, that the acid Parts of the Air dissolve or attenuate the Blood in the Lungs.

Oil of Vitriol and Water poured successively into the same Vessel, grow very hot in the mixing. *Aqua fortis*, or Spirit of Vitriol, poured upon Filings of Iron, dissolves the Filings with a great Heat and Ebullition. And the Acid of the Air constantly apply'd to sulphureous and unctuous Substances, when once they are kindled, continues to dissolve them with the Heat of Fire and Flame.

From these Experiments we learn, that it is the Nature of Acids to dissolve Bodies with Heat; and therefore, since I have shewn that the Acid of the Air dissolves the Blood; it must be allowed, that it warms the  
the



the Blood at the same time it dissolves it.

When Animals are deprived of the Acid of the Air, the Pulse in less than one Minute of Time becomes small and quick; as may be observed in a Dog, when his Lungs are made flaccid and without Motion by laying open his Thorax. Upon emptying my Lungs of Air as much as I could, and then stopping my Breath; my Pulse has grown small and quick, with a kind of trembling convulsive Motion, in less than half a Minute of Time. And *Thruston* observed the Pulse to grow smaller on an Intermission of Respiration, and greater again on repeating it.

Hence it appears, that the Motion of the Heart lessens immediately on Animals being deprived of the Acid of the Air; and consequently, that this Acid by dissolving  
ing

ing or attenuating the Blood and preserving its Heat, keeps up the Motion of the Heart.

Therefore the *Proposition* is true.

But tho' this *Proposition* be fully proved; yet to obviate Objections, I think it not improper to prove the following Particulars by Experiments and Observations.

1. The Motion of the Lungs in breathing is no otherwise necessary to the Life of Animals, than as by this Motion the Lungs receive a constant Supply of fresh Air.

This is proved by the following Experiment. *Hook*, after he had laid open the Thorax of a Dog, cut away his Ribs and Diaphragm, and taken off the Pericardium, kept him alive before the *Royal Society* of *London* above an Hour, by blowing fresh Air into his Lungs with a pair

pair of Bellows. It was observed, that as often as he left off blowing, and suffered the Lungs to subside and lie still, the Dog presently fell into dying convulsive Motions, and soon recovered again on renewing the Blast. After he had done this several Times with like Success, he pricked all the outer Coat of the Lungs with the slender Point of a sharp Penknife, and by a constant Blast made with a double pair of Bellows, he kept the Lungs always distended and without Motion; and it was observed, that while the Lungs were thus kept distended with a constant Supply of fresh Air, the Dog lay still, his Eyes were quick, and his Heart beat regularly; but that upon leaving off blowing, and suffering the Lungs to subside and lie still, the Dog presently fell into dying convulsive Motions, and as soon recovered again on renewing the Blast,



Blast, and supplying the Lungs with fresh Air.

2. The Motion of the Lungs in breathing does not change the Colour of the Blood in that Part.

This is proved by the following Experiment. *Lower* opened the Pulmonary Vein of a Dog near the left Auricle of the Heart, when his Lungs were kept distended and without Motion by a constant Supply of fresh Air; and observed the Blood drawn to have the same florid Colour, as the Arterial Blood of other Parts.

Farther, If the Motion of the Lungs change the Colour of the Blood from a dark Purple to a bright Red; I see no Reason, why the Motion of the Muscles when continued for some Time should not keep up that red Colour in the Veins; and consequently, why under strong Exercise Venal Blood (contrary to  
Expe-

Experience) should not be of a bright red Colour. For a strong and vigorous Motion of the Muscles must undoubtedly contribute as much to preserve the bright red Colour of Arterial Blood, as the Motion of the Lungs contributes to produce it.

3. The Death of Animals and Extinction of Flame in a confined Air, are not caused by a Diminution of its Elasticity.

For there is sometimes as great a Diminution of Elasticity in the Air in violent Storms of Wind and Hurricanes, as there is in a small Quantity of confined Air at the Time when Animals die and Candles go out in it; and yet no such Effects follow. Farther, If Animals die and Candles go out in a confined Air, from a Diminution of its Elasticity; then these Effects would not be produced in different Quantities of confined Air, until its Elasticity

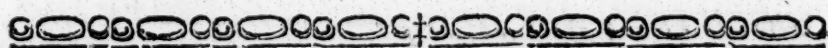
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was

was equally diminished in them: But it has been found by Experiments, that at the Time when Animals die and Candles go out in two different Quantities of confined Air, there is a greater Diminution of Elasticity in the smaller Quantity than in the greater: And therefore, Life and Flame are not destroyed by a Diminution of the Elasticity of the Air. This is farther confirmed from an Experiment mentioned above; For if effete Air, however forcibly blown on live Coals, extinguishes them in like Manner as it does when in a State of Rest; then the same effete Air, which in a quiescent State cannot preserve Life, will not be able to do it when it is pressed into the Lungs with any Force, even a greater than is sufficient to swell the Air-Vessels to their usual Magnitudes: And therefore Animals do not die  
in



in a confined Air, from the *Vesiculæ* not being sufficiently dilated on account of a Diminution of the Elasticity of the Air. A Diminution of the Elasticity of the Air is no otherwise hurtful, than as it hinders the Vesicles from being sufficiently dilated, and thereby hinders the Blood from receiving its usual Quantity of Acid in a given Time: Whence the Blood will not be sufficiently dissolved and warmed in the Lungs; which will make Respiration quick and uneasy, but cannot cause sudden Death.



### Proposition XXV.

*IF* healthful Bodies be cloathed alike, and placed in a Wind blowing uniformly, or move gently along in a calm and still Air with the same uniform Motion; and if Heat be generated

*nerated in their Blood by the Acid of the Air, as fast as it is lost by being communicated to the Air in their Lungs and at their Skins: The Heats generated in their Blood in a short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together directly; and as the Degrees of Heat in the Wind or calm Air inversely. If S, s denote the Sums of the said Surfaces of two healthful Bodies; H, h the Degrees of Heat in their Blood when they are first plac'd in the Wind, or begin to move in a calm and still Air; A, a the Degrees of Heat in the Wind or Air; and G, g the Heats generated in their Blood by the Acid of the Air in a short given Time: I say, that  $G. g :: \frac{SH}{A} \cdot \frac{sh}{a}.$*

For

For since the Bodies are supposed to be cloathed alike, the external Surfaces of their Bodies will be alike exposed to the Air; and the internal Surfaces of their Systems of Air-Vessels are always alike exposed to it, on account of Respiration; and since it is the same thing to move gently along in a calm and still Air with an uniform Motion, as to stand still in a Wind blowing with the same uniform Motion: It is evident by the 23<sup>d</sup> *Proposition*, that the Heats communicated to the Air and lost in the Blood of healthful Bodies in a very short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together directly; and the Degrees of Heat in the Wind or Air inversely: But by *Supposition*, the Heat is generated by  
the



the Acid of the Air as fast as it is lost by being communicated to the Air in the Lungs and at the Skin: And therefore, the Heats generated by the Acid of the Air in the Blood of healthful Bodies in a short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together, directly; and the Degrees of Heat in the Wind or Air, inversely; that is,  $G. g :: \frac{SH}{A} \cdot \frac{sh}{a}$ .

*Cor. 1.* If the Degrees of Heat in the Blood of Bodies under the Circumstances supposed in this *Proposition*, and the Degrees of Heat in the Wind or calm Air be respectively equal; the Heats generated in the Blood by the Acid of the Air in a given Time, will be as the Sums  
of

of the internal Surfaces of the Systems of Air-Vessels and external Surfaces of the Bodies. If  $H=h$ , and  $A=a$ ; then will  $G. g :: S. s$ .

From some Experiments made with a Thermometer at the same Time and in the same Place, I have found the Heats of the warmest Parts of the Skin, and consequently the Heats of the Blood, to be nearly equal in healthful Bodies of all Ages, notwithstanding the Limbs of old Bodies are considerably colder than the Limbs of young Bodies, or Bodies of a middle Age: And if by a larger Experience, this shall be found to be universally true; then will this *Corollary* obtain in all healthful Bodies in the same Place and at the same Time: And as these Experiments were made when the Bodies were at Rest, and the Air still and calm, so this *Corollary* will likewise obtain

obtain nearly in Bodies at Rest in a calm and still Air, in the same Place and at the same Time: And granting this, and supposing the external Surfaces of the Bodies to be proportional to the whole internal Surfaces of their Systems of Air-Vessels, and those whole Surfaces to be proportional to the internal Surfaces of all their Vesicles thro' which the Acid of the Air passes into their Blood; then will the Heats generated in a short given Time in the Blood of healthful Bodies, in the same Place and at the same Time, be as the internal Surfaces of all the Vesicles of their respective Systems of Air-Vessels: And if the Vesicles attract the acid Parts of the Air, in Proportion to the Magnitudes of their internal Surfaces, (as I have shewn the Blood-Vessels to act on the Blood by attractive or some other Powers, in Proportion to the  
Mag-



Magnitudes of their internal Surfaces) then will the Heats generated in the Blood by the Acid of the Air in a short given Time, be as the attractive Powers of all the Vesicles.

*Cor. 2.* If the Degrees of Heat in the Blood of Bodies under the Circumstances supposed in this *Proposition* be equal; the Heats generated in it by the Acid of the Air in a short given Time, will be as the Sums of the internal Surfaces of the Systems of Air-Vessels and external Surfaces of the Bodies, directly; and the Degrees of Heat in the Wind or calm Air, inversely: If  $H=h$ , then will  $G. g :: \frac{S}{A} \cdot \frac{s}{a}$ .

If by the *Thermometer* it shall be found, that the Degree of Heat in the Blood of healthful Bodies is much the same at all Seasons of the  
D d                      Year,

Year, and in all Climates; then by this *Corollary*, more or less Heat will be generated in the Blood of the same Body in a given Time, as the Air is colder or hotter; which cannot be, unless the Air when it is cold abounds more with this Acid, than when it is hot: And that it does so, appears from Fire burning best when the Air is coldest, and worst when it is hottest. Now if the Air be cooled by the same Acid which generates Heat in the Blood when mixed with it; then as the Air abounds more or less with this Acid, the Air will be colder or hotter; and more or less Heat will be both generated and lost in the Blood, in a given Time.

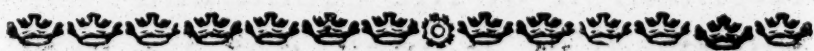
By the 24<sup>th</sup> *Proposition*, the Acid of the Air dissolves or attenuates the Blood, at the same Time it generates Heat in it; and the Dissolution or Attenuation will be greater or less, as more or less of this  
this

this Acid is mixed with the Blood in a given Time: And therefore the Blood will be more dissolved or attenuated in Winter than in Summer, in cold Countries than in hot. And if the Want of a sufficient Dissolution or Attenuation of the Blood be the Cause of *Malignant Diseases*; Bodies will be more subject to such Diseases in Summer and hot Countries, than in Winter and cold Countries.

This is the general Law of the Attenuation of the Blood, and Heat generated in it, in a given Time, on Supposition that the Degree of Heat in the Blood is given: However, it may sometimes happen, that the Attenuation of the Blood and Heat generated in it may not be proportional to the Degree of Coldness in the Air. For the Air may be so excessively cold, and so greatly saturated with this Acid, that the mu-



tual Attraction of its Particles, arising from their Closeness to one another, may hinder them from being drawn into the Blood in as great a Quantity, as when the Air abounds less with them: And whenever this happens, the Fluidity and Heat of the Blood will be destroyed faster than they are generated; and if this continues for any Time, it must of Necessity put an End to Life. The Case here is much the same as in Oil of Vitriol, and some other Acids; which from their too great Strength will not dissolve Metals so quickly, nor raise so great a Heat, as the same Acids when made weaker.



Proposition XXVI.

***I**F healthful Bodies be situated alike  
with respect to the Horizon, if  
the*

*the Motions of their Hearts and Lungs be free from the Influences of all disturbing Causes, if the mean Capacities of their Systems of Air-Vessels be proportional to the mean Capacities of their Systems of Blood-Vessels, and if the mean Numbers of their Inspirations in a given Time be proportional to the mean Numbers of their Pulses in that Time; the mean Quantities of fresh Air inspired, will be as the mean Quantities of Blood which flow thro' their Lungs in the given Time.*

Since by Supposition, the Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; the mean Capacities of the Systems of Blood-Vessels of Bodies of different Lengths, will be as the mean Capacities of corresponding Vessels, that is, as the Squares of their mean Diameters into their Lengths,

Lengths, or into the Lengths of the Bodies ; therefore, the mean Capacities of the Systems of Blood-Vessels of Bodies of two different Lengths, will be as  $D^2L$  and  $d^2l$ ,  $D$  and  $d$  denoting the mean Diameters of any two corresponding Vessels, and  $L$  and  $l$  the Lengths of the Bodies : Since likewise by Supposition, the mean Capacities of the Systems of Air-Vessels are as the mean Capacities of the Systems of Blood-Vessels ; the mean Capacities of the Systems of Air-Vessels of Bodies of two different Lengths, will be as  $D^2L$  and  $d^2l$ , when the Bodies are fitting and their Hearts free from the Influences of all disturbing Causes : And since also by Supposition, the mean Numbers of Inspirations are as the mean Numbers of Pulses in a given Time ; the mean Quantities of fresh Air inspired by healthful Bodies of two different Lengths, will



will be as the mean Capacities of their Systems of Air-Vessels and mean Numbers of their Pulses in that Time taken together, that is, as  $D^{\circ}LP$  and  $d^{\circ}lp$ ,  $P$  and  $p$  denoting the mean Numbers of Pulses in the given Time: But by the *first Corollary* of the 14th Proposition,  $P.p :: \frac{V}{L} \cdot \frac{v}{l}$ : And therefore, the Quantities of fresh Air inspired in a given Time will be as  $D^{\circ}V$  and  $d^{\circ}v$ , that is, as the mean Quantities of Blood which flow thro' the Lungs in the given Time.

The mean Numbers of Pulses and Inspirations in a Minute of healthful Bodies of three different Lengths, in the Morning when they were sitting, were 65, 72, 116, and 17, 19, 30. Hence it appears, that the mean Numbers of Pulses and Inspirations in a given Time, are proportional to one another in health-

healthful Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes: And if from Experiments it shall be found, that the mean Capacities of the Systems of Air-Vessels are proportional to the mean Capacities of the Systems of Blood-Vessels; then will this *Proposition* be true in healthful Bodies.

*Cor. 1.* If this *Proposition* be true; the mean Quantities of fresh Air inspired in a given Time by healthful Bodies, will be in Ratios compounded of the duplicate and subduplicate Ratios of the mean Diameters of corresponding Blood-Vessels, that is, as  $D^2\sqrt{D}$  and  $d^2\sqrt{d}$ . For  $V.v :: \sqrt{D}.\sqrt{d}$ , by the *Twelfth Proposition*: But the Quantities of fresh Air inspired in a given Time, are as  $D^2V$  and  $d^2v$ , by this *Proposition*:

*sition*: And therefore, the Quantities of fresh Air inspired in a given Time will be as  $D^2\sqrt{D}$  and  $d^2\sqrt{d}$ .

*Cor. 2.* If this *Proposition* be true; the mean Quantities of Air inspired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies, that is,  $L \times L^{\frac{1}{4}}$  and  $l \times l^{\frac{1}{4}}$ . For  $D.d :: L^{\frac{1}{2}}. l^{\frac{1}{2}}$ , by *Cor. 4. Prop. 12*; and by Consequence,  $D^2\sqrt{D}. d^2\sqrt{d} :: L \times L^{\frac{1}{4}}. l \times l^{\frac{1}{4}}$ : But the mean Quantities are as  $D^2\sqrt{D}$  and  $d^2\sqrt{d}$ , by the last *Corollary*: And therefore, they will be as  $L \times L^{\frac{1}{4}}$  and  $l \times l^{\frac{1}{4}}$ .

*Cor. 3.* If this *Proposition* be true; the mean Quantities of Air inspired in a given Time by healthful Bodies of different Lengths, will be in

E e                      Ratios



Ratios compounded of the duplicate Ratios of the Lengths of the Bodies and the simple Ratios of the Numbers of their Pulses in a given Time, that is, as  $L^2P$  and  $l^2p$ . For by this *Proposition*, the mean Quantities of Air inspired in a given Time are as  $D^2V$  and  $d^2v$ : But by *Cor. 4. Prop. 12*,  $D^2.d^2::L.l$ , and by *Cor. 1. Prop. 14*,  $V.v::LP.lp$ : And therefore, the mean Quantities of Air inspired in a given Time will be as  $L^2P$  and  $l^2p$ .

*Cor. 4.* If this *Proposition* be true; the Quantities of fresh Air inspired in a given Time in Proportion to the whole Quantities of Blood, will be as the Numbers of Pulses in a given Time. For  $\frac{V}{L} \cdot \frac{v}{l} :: P.p$ , by *Cor. 1. Prop. 14*: But  $\frac{V}{L} \cdot \frac{v}{l} :: \frac{D^2V}{D^2L} \cdot \frac{d^2v}{d^2l}$ :  
And therefore,  $\frac{D^2V}{D^2L} \cdot \frac{d^2v}{d^2l} :: P.p$ .

S E C-

SECTION III.

*Of Digestion and Nutrition, Secretion, and the Discharges of Human Bodies.*

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*Of Digestion and Nutrition.*

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Proposition XXVII.

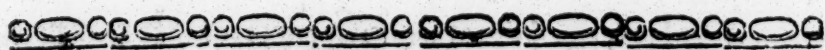
**T**HE Nourishment of Animals changes its Texture in their Bodies, till it becomes like their solid and durable Parts.

For the solid and durable Parts of Animal Bodies grow out of their Nourishment: But their Growth is from an Addition and Adhesion of like Parts: And therefore, the Nourishment of Animals changes its

Texture in their Bodies till it becomes like their solid and durable Parts.

*Cor. 1.* Hence it appears, that Animals will not be rightly nourished, when their Nourishment does not change its Texture in their Bodies till it becomes like their solid and durable Parts.

*Cor. 2.* Hence it appears, that the Nourishment, by changing its Texture in the Bodies of Animals, becomes more dry and earthy than it was before; otherwise, it would not be like their solid and durable Parts.



### Proposition XXVIII.

**T**HE *Texture of the Nourishment is changed in the Bodies of Animals, by a gentle Heat and Motion.*

The



The first remarkable Change in the Texture of the Nourishment is made in the Stomach: In this Bow-el the solid Parts of the Food are dissolved and intimately mixed with the Fluids. This Mixture is usually called *Chyle*.

Some, from observing that Fluids have a Power of dissolving Bodies, have thought that a Fluid in the Stomach dissolves the Food and turns it into Chyle: But as it does not appear from Experiments and Observations, that there is a Fluid in the Stomach endued with such a Power; this Opinion is without Foundation.

Others, from observing the great Strength of the Gizzards of Fowls, and that there is commonly Gravel found in them, have imagined, that the Food is dissolved in the Stomachs of Fowls, and consequently in the Stomachs of all Animals, by  
Attri-

Attrition or Grinding. But if this Opinion be examined, it will likewise appear to be without Foundation. For the Food of Fowls is mostly Grain, all Sorts of which are hard and covered with tough Skins; and therefore, before this Food can be dissolved and turned into Chyle, it must be softened, and its Skins ground off; the first of which is done by Warmth and Moisture in the Craw, and the second by Attrition in the Gizzard. By these Contrivances, the Food of Fowl is prepared and fitted for Digestion; as human Food is by Cookery and other Ways of preparing it, and by the grinding of the Teeth. But if we should grant, that the Food of Fowl is dissolved and turned into Chyle by Attrition; it will by no means follow, that Food is so dissolved and turned into Chyle in a human Stomach, which has no Gravel

vel in it, and has but very little Muscular Strength in Comparison of the Gizzards of Fowls. There may be many different Contrivances in different Species of Animals, to soften, grossly divide, and prepare their Food for Digestion; but it will not from thence follow, that their Food is digested or turned into Chyle by different Causes.

The Food is dissolved and turned into Chyle by a gentle Heat and Motion. Heat makes many Bodies fluid, which are not fluid in Cold. Lead is melted by a Heat eight times as great as the external Heat of a human Body; Tin, by a Heat six times as great; Wax, by a Heat twice as great; and Bones, with the Addition of a little Water, are dissolved in a Digester by Heat in a little Time. If the Heat of the Stomach be nearly equal to that of the Blood; this Heat, tho' gentle, may be sufficient, when

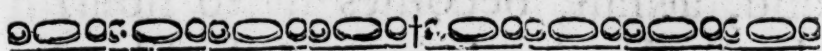


when the Orifices of the Stomach are pretty exactly closed, to dissolve the Food in a few Hours, and turn it into Chyle ; especially, when it is assisted by the Motion of the Stomach, which by agitating and mixing the Food will contribute to this End. For since Heat can dissolve solid Bodies, and nothing is found in a human Stomach, besides a gentle Heat and Motion, which can dissolve the Food and turn it into Chyle ; it will follow, that the Food is digested or dissolved, and turned into Chyle, by a gentle Heat and Motion.

The Chyle in moving through the Intestines is farther dissolved by Heat and Motion : And the finest Part of this Fluid being conveyed into the Blood, is still farther changed by the same Causes, namely a gentle Heat and Motion, till it puts on the Form of Blood,  
and,

and, at last, becomes fit to nourish the Body, by being made like its solid and durable Parts. The Growth of the Pullet in the Shell out of the White of the Egg, is a strong Proof of the Truth of this: For here is manifestly nothing, besides a gentle Heat and Motion, to change the White of the Egg, so as to convert it into Blood, and render it fit Nourishment for all the Parts of an Animal Body.

*Cor.* Hence Animals will not be rightly nourished, when the Texture of their Food is not rightly changed in their Bodies by Heat and Motion; which may be owing, either to an Unfitness in the Food for such a Change, or to Degrees of Heat and Motion unfit to effect it.



## Proposition XXIX.

**T**HE *constituent solid Parts of Animals, according to their several Natures, are endued with peculiar attractive Powers of certain Magnitudes; by which they draw out of the Fluids moving thro' them like Parts in certain Quantities, and thereby preserve their Forms and just Magnitudes.*

For without attractive Powers agreeable to their Natures, the constituent solid Parts of Animals cannot draw like Particles out of the Fluids moving through them; and consequently, cannot preserve their Forms: And unless these Powers be of certain Magnitudes, they cannot draw those Parts in such Quantities as are proper to preserve their Magnitudes:



nitudes : And therefore, the *Proposition* is true.

*Cor. 1.* Hence Bodies will not be rightly nourished by proper Food changed by just Degrees of Heat and Motion, when the attractive Powers of their solid Parts are changed, either in their Natures, or in their Magnitudes.

*Cor. 2.* Hence Animals of the same Species will grow faster or slower, out of the same Nourishment rightly changed by Heat and Motion ; as the attractive Powers of their solid Parts are stronger or weaker. And universally, their Growth in a given Time will be greater or less ; as the attractive Powers of corresponding Parts are greater or less ; or as the Fluids moving thro' those Parts abound more or less with similar Particles, that is, with Parti-

228     *A Treatise of the*  
cles rightly fitted to be attracted by  
those Powers.

*General Scholium.*

I have shewn that the Nourishment of Animals becomes more dry and earthy in their Bodies, and that this Change is effected by a gentle Heat and Motion. How a gentle Heat and Motion cause this Change in the Nourishment, may be understood from what Sir *Isaac Newton* has delivered concerning the Nature of Salt. This great Man, finding from Experiments and Observations, that Salts are dry Earth and watry Acid united by Attraction, and that the Earth will not become a Salt without so much Acid as makes it dissolvable in Water, has given the following Account of the Formation of Particles of Salt.

“ As Gravity makes the Sea flow  
“ round the denser and weightier  
“ Parts

“ Parts of the Globe of the Earth,  
 “ so the Attraction may make the  
 “ watry Acid flow round the den-  
 “ ser and compacter Particles of  
 “ Earth for composing the Parti-  
 “ cles of Salt. For otherwise the  
 “ Acid would not do the Office of  
 “ a Medium between the Earth and  
 “ common Water, for making Salts  
 “ dissolvable in Water; nor would  
 “ *Salt of Tartar* readily draw off  
 “ the Acid from dissolved Metals,  
 “ nor Metals the Acid from *Mer-*  
 “ *cury*. Now as in the great Globe  
 “ of the Earth and Sea, the densest  
 “ Bodies by their Gravity sink down  
 “ in Water, and always endeavour  
 “ to go towards the Centre of the  
 “ Globe; so in Particles of Salt,  
 “ the densest Matter may always  
 “ endeavour to approach the Cen-  
 “ ter of the Particle: So that a Par-  
 “ ticle of Salt may be compared to  
 “ a Chaos; being dense, hard, dry,  
 “ and



“ and earthy in the Center ; and  
“ rare, soft, moist, and watry  
“ in the Circumference. And  
“ hence it seems to be that Salts  
“ are of a lasting Nature, being  
“ scarce destroy’d, unless by draw-  
“ ing away their watry Parts by  
“ Violence, or by letting them soak  
“ into the Pores of the Central  
“ Earth by a gentle Heat in Pu-  
“ trefaction, until the Earth be dis-  
“ solved by the Water, and separa-  
“ ted into smaller Particles, which  
“ by reason of their Smallness make  
“ the rotten Compound appear of  
“ a black Colour. Hence also it  
“ may be that the Parts of Ani-  
“ mals and Vegetables preserve  
“ their several Forms, and assimi-  
“ milate their Nourishment ; the  
“ soft and moist Nourishment ea-  
“ sily changing its Texture by a  
“ gentle Heat and Motion, till it  
“ becomes like the dense, hard,  
“ dry,

“ dry, and durable Earth in the  
 “ Center of each Particle. But  
 “ when the Nourishment grows un-  
 “ fit to be assimilated, or the Cen-  
 “ tral Earth grows too feeble to assi-  
 “ milate it, the Motion ends in Con-  
 “ fusion, Putrefaction and Death.  
*Newt. Opt. p. 361, 362.*

Hence it appears, that to render  
 the saline Part of the Aliment fit to  
 nourish the solid Parts of Animals  
 and Vegetables, part of the super-  
 ficial watry Acid must by Heat and  
 Motion be drawn off from the Par-  
 ticles of Salt; by which they will  
 become more dense, hard, dry and  
 earthy, like the solid and durable  
 Parts of the Bodies. And, accord-  
 ing to the different Degrees of Heat  
 and Motion in the different Species  
 of Animals and Vegetables, the wa-  
 try Moisture will be drawn off in  
 different Proportions, so as in each  
 Species to render the Particles like  
 the

the solid Parts of the Bodies of that Species.

And farther, if we consider that Water is a very fluid tasteless Salt, and that Animals and Vegetables, with their several Parts, grow out of Water and watry Tinctures and Salts ; we may from what has been said understand the Manner in which the Nourishment of Animals and Vegetables is changed by a gentle Heat and Motion, till it becomes like the solid and durable Parts of their respective Bodies.



*Of*



*Of Secretion.*

### Proposition XXX.

**T**HE Glands in the Bodies of Animals, according to their several Natures and Dispositions, are endued with peculiar attractive Powers by which they suck in various Juices from the Blood.

That the Glands of Animals have such attractive Powers, I shall prove from Experiments and Observations.

“ If two plane polished Plates of  
 “ Glas (suppose two Pieces of a  
 “ polished Looking-Glas) be laid  
 “ together, so that their Sides be  
 “ parallel and at a very small Di-  
 “ stance from one another, and  
 “ then their lower Edges be dip-  
 G g “ ped

“ ped into Water, the Water will  
“ rise up between them. And the  
“ less the Distance of the Glasses is,  
“ the greater will be the Height to  
“ which the Water will rise. If  
“ the Distance be about the hundredth  
“ part of an Inch, the Water  
“ will rise to the Height of about  
“ an Inch; and if the Distance be  
“ greater or less in any Proportion,  
“ the Height will be reciprocally  
“ proportional to the Distance very nearly. The Weight  
“ of the Water drawn up being the  
“ same, whether the Distance between  
“ the Glasses be greater or less;  
“ the Force which raises the Water  
“ and suspends it must be likewise  
“ the same, and suffer no Change  
“ by changing the Distance of the  
“ Glasses. And in like Manner,  
“ Water ascends between two  
“ Marbles polished plane, when their  
“ polished Sides  
“ are

“ are parallel and at a very little  
 “ Distance from one another. And  
 “ if slender Pipes of Glass be dip-  
 “ ped at one End into stagnating  
 “ Water, the Water will rise up  
 “ within the Pipe, and the Height  
 “ to which it rises will be recipro-  
 “ cally proportional to the Dia-  
 “ meter of the Cavity of the Pipe,  
 “ and will equal the Height to  
 “ which it rises between two Planes  
 “ of Glass, if the Semidiameter of  
 “ the Cavity of the Pipe be equal  
 “ to the Distance between the  
 “ Planes, or thereabouts. And  
 “ these Experiments succeed after  
 “ the same Manner *in vacuo* as in  
 “ the open Air, (as hath been try’d  
 “ before the *Royal Society*,) and  
 “ therefore are not influenced by  
 “ the Weight or Pressure of the At-  
 “ mosphere. See *Newt. Opt. p.*  
 366, 367.



Now since the Rise and Suspension of Water between two Glass Planes and in small Glass Pipes, are not owing to the Pressure of the Atmosphere; they must be caused by an attractive Power in the Glass, which will be proportional to the Weight of Water sustained by it. Let  $H, h$  denote the Heights of the Column of Water sustained between the two Glass Planes and of the Cylinder sustained in a small Glass Pipe;  $B, p$  the Breadth of the Column and Periphery of the Cylinder; and  $D, d$  the Thickness of the Column and Diameter of the Cylinder: And then the attractive Power which sustains the Column will be as  $HBD$ , or as  $B$ , because  $H$  is as  $\frac{1}{D}$ ; and the attractive Power which sustains the Cylinder will be as  $\frac{hpd}{4}$ , or as  $\frac{p}{4}$ , or as  $p$ , because  $h$  is as  $\frac{1}{d}$ .

Hence

Hence it appears, that the attractive Power which sustains the Water arises only from those Parts of the Glass which are contiguous to the Surface of the elevated Water; or more truly, from the Parts of a narrow Surface of the Glass, whose Edge touches the lower Surface of the Water, and whose Height is the small given Distance to which the attractive Power with which Glass attracts Water reaches; and therefore, the attractive Powers of the Glass Planes and small Glass Pipe will be as  $2B$  and  $p$ . Now the Powers are as the Weights sustained by them, that is,  $2B. p :: H B D. \frac{hpd}{4}$ : Whence  $HD$  will be equal to  $\frac{hd}{2}$ ; and when  $D$  is equal to  $\frac{d}{2}$ ,  $H$  will be equal to  $h$ .

One and the same small Glass Pipe will sustain different Weights of different Fluids, as appears from this Table :

Fluids.	Heights in Inches.	Densities.	Weights.
Oil of Vitriol	I. 1	17245	18969
Water p. 6. Sal Gem p. $\frac{3}{4}$	I. 73	10921	18893
Water p. 6. Sal Gem p. $\frac{1}{2}$	I. 72	10642	18304
Water p. 8. Common Salt p. $\frac{1}{2}$	I. 67	10447	17446
Water p. 6. Salt-petre p. $\frac{1}{2}$	I. 71	10447	17864
Spirit of Vitriol	I. 63	11860	19331
German Spa-Water	I. 75	10111	17694
Common Water cold	I. 75	10000	17500
Common Water boiling hot	I. 64	9781	15040
Good Blood	I. 64	10400	17056
Serum of good Blood	I. 65	10300	16995
Serum in a Dropsy	I. 65	10171	16782
Urine	I. 60	10270	16432
Saliva	I. 54	10100	15554
Milk of a Cow	I. 42	10279	14596
Gall of an Ox	I. 2	10335	12402
Small Beer	I. 44	10111	14559
Cyder	I. 3	10111	13144
Vinegar	I. 23	10279	12643
Common Ale	I. 2	10300	12360
Red Wine	I. 15	9930	11419
Punch	I. 12	10055	11261
Oil Olive	I. 14	9130	10408
Oil of Turpentine	O. 81	9244	7487
Sal Volatile Oleosum	O. 84	8774	7370
Brandy	O. 75	9320	6990
Spirit of Wine rectified	O. 73	8324	6076
Spirit of Harts-horn	I. 44	9802	14114

In



In the first Column are the Names of the Fluids, in the second the Heights to which they rose in one and the same Glass Pipe, in the third the Densities of the Fluids, and in the fourth the Weights sustained by the same Pipe. I obtained the Weights by multiplying the Heights into the Densities. For the Weights of Cylinders are as their Magnitudes and Densities taken together, or as their Heights and Densities taken together if their Bases be equal: But the Bases of all the Cylinders of different Fluids sustained by one and the same Pipe are equal: And therefore, the Weights of such Cylinders are as their Heights and Densities taken together.

Hence it appears, that one and the same Glass Pipe attracts different Fluids with different Degrees of Force. It attracts Spirit of Vitriol more strongly than Oil of Vitriol, Oil of  
 Vitriol

Vitriol more strongly than Water impregnated with Salt, Water impregnated with Sal Gem and Nitre more strongly than common Water cold, common Water cold more strongly than the Animal Fluids and common Water made boiling hot, the Animal Fluids more strongly than fermented Liquors, fermented Liquors more strongly than Oils, and Oils more strongly than ardent Spirits.

Since the same Glass Pipe attracts different Fluids with different Degrees of Force; it is evident, that it attracts the Parts of some Fluids more strongly than those of others; and by Consequence, if equal Quantities of all the Fluids of this Table were mixed together, it would suck in different Parts of this heterogeneous Fluid in different Proportions. It would suck in more Parts of Water impregnated with Salt  
than

than of Oil or ardent Spirits. The Parts least attracted would be driven off, to make way for those which are most attracted to enter into the Pipe; as in a Fluid where the Force of Gravity alone takes place the lighter Bodies are forced to ascend, to make way for the Descent of Bodies which are heavier.

Sir *Isaac Newton* has proved from Experiments, that the Particles of Light attract ardent Spirits and Oil more strongly than Water: And by Consequence, if we suppose a small Pipe to be formed out of the Particles of Light, and one End of it to be dipped into a heterogeneous Fluid formed out of equal Quantities of all the Fluids of this Table intimately mixed together; this Pipe would attract the Parts of Oil and ardent Spirits more strongly than those of Water, and would suck in

H h

more



more Parts of the two former than of the latter. The Fluid therefore drawn out of the heterogeneous Fluid by this Pipe, would be different from the Fluid drawn out of it by a small Glass Pipe ; for two Fluids will be different, when they either consist of different Parts, or of the same Parts mixed in different Proportions.

Now since Pipes of different Natures must draw off different Fluids from one and the same heterogeneous Fluid ; it follows, that the secreting Pipes of the Glands, according to their different Natures and Dispositions, suck in various Juices from the Blood, which is a heterogeneous Fluid consisting of a great Variety of Parts. And consequently, the *Proposition* is true.

Propo-



## Proposition XXXI.

*IF Human Bodies have the same Number of corresponding Glands, if corresponding Glands have the same Number of corresponding secerning Pipes arising out of corresponding Blood-Vessels, if the Lengths of corresponding Pipes be as the Lengths of the Bodies, if the Bodies be situated alike with respect to the Horizon, their Hearts be alike free from the Influences of disturbing Causes, and their Blood be alike saturated with Parts fit for Secretion; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the sesquipli- cate Ratios of the Diameters of corresponding Blood-Vessels and of the subduplicate Ratios of the Forces which move the secerned Humours through*

H h 2

cor-

*corresponding secerning Pipes, directly; and of the subduplicate Ratios of the Lengths of the Bodies, inversely. If Z, z denote the Quantities discharged by two corresponding Glands in a given Time; F, f the Forces which move the Humours through two corresponding secerning Pipes; D, d the Diameters of two corresponding Blood-Vessels; and L, l the Lengths of the Bodies; I say, that  $Z. z :: D \sqrt{\frac{DF}{L}}. d \sqrt{\frac{df}{l}}.$*

For, allowing the Suppositions made in this *Proposition* to be true, it is evident, that the Quantities of Humour discharged by corresponding Glands in a given Time, will be as the Quantities discharged by any of their corresponding secerning Pipes in that Time: But the Quantities discharged by corresponding secerning Pipes in a given Time,



Time, will be as the Squares of their Diameters and the Velocities of the Humour flowing thro' them taken together ; or as the Squares of the Diameters of the Blood-Vessels out of which the Pipes arise and the Velocities of the Humour flowing through the Pipes taken together, because the Diameters of the Pipes are as the Diameters of the Blood-Vessels out of which they arise ; and the Velocities of the Humour flowing thro' corresponding Pipes, will by *Prop. 1.* be in Ratios compounded of the direct subduplicate Ratios of the Forces which move the Humour thro' them ; and the inverse subduplicate Ratios of the Diameters and of the Lengths of the Pipes, or of the Diameters of corresponding Blood-Vessels and of the Lengths of the Bodies : And therefore, allowing the Suppositions in this *Proposition*, the Quantities

tities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of corresponding Blood-Vessels and of the subduplicate Ratios of the Forces which move the Humour thro' corresponding secerning Pipes, directly; and of the subduplicate Ratios of the Diameters of corresponding Blood-Vessels and of the Lengths of the Bodies, inverfly; that is,  $Z. z :: D^2 \sqrt{\frac{F}{DL}} \cdot d^2 \sqrt{\frac{f}{dl}} \cdot \text{But } D^2 \sqrt{\frac{F}{DL}} \cdot d^2 \sqrt{\frac{f}{dl}} :: D \sqrt{\frac{DF}{L}} \cdot d \sqrt{\frac{df}{l}}$ : And therefore,  $Z. z :: D \sqrt{\frac{DF}{L}} \cdot d \sqrt{\frac{df}{l}}$ .

*Cor. 1.* If this *Proposition* be true, and if the moving Forces of corresponding secerning Pipes be as their Diameters, or as the Diameters of corresponding Blood-Vessels; the Quantities of Humour discharged by

by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of corresponding Blood-Vessels directly, and of the subduplicate Ratios of the Lengths of the Bodies inversly. And the mean Quantities of Humour discharged in a given Time, will be in subduplicate Ratios of the Lengths of the Bodies.

If  $F. f :: D. d$ ; then will  $Z. z :: \frac{D^2}{\sqrt{L}}$ .

$\frac{d^2}{\sqrt{l}}$ . And since by *Cor. 4. Prop. 12.* the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, are in the subduplicate Ratios of the Lengths of the Bodies; if  $D, d$  denote the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and  $Z, z$  the mean Quantities of Humour discharged by corresponding Glands in a given Time<sup>s</sup>; then  $Z. z :: \sqrt{L. l}$ .

*Cor.*



*Cor. 2.* If this *Proposition* be true, and if the moving Forces of corresponding fecerning Pipes be as the internal Surfaces of the Pipes, that is, as their Diameters and Lengths taken together, or as the Diameters of corresponding Blood-Vessels and Lengths of the Bodies taken together; the Quantities discharged by corresponding Glands in a given Time, will be in the duplicate Ratios of the Diameters of corresponding Blood-Vessels. And the mean Quantities discharged by corresponding Glands in a given Time will be as the Lengths of the Bodies. If  $F. f :: D L. d l$ ; then will  $Z. z :: D^2. d^2$ . And, supposing  $D, d, Z, z$  to denote mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and mean Quantities of Humour discharged by corresponding Glands in a given Time; then  $Z. z :: L. l$ .

*Cor.*

*Cor. 3.* If this *Proposition* be true, and if the moving Forces of corresponding fecerning Pipes be as the Capacities of the Pipes, or as the Capacities of corresponding Blood-Vessels; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels. And the mean Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies. If  $F.f :: D^2L. d^2l$ ; then will  $Z. z :: D^2\sqrt{D}. d^2\sqrt{d}$ . And supposing  $D, d, Z, z$  to denote mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, and mean Quantities of Humour discharged by corresponding Glands in a given

I i                      Time;

Time ; then, since the mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths are in the subduplicate Ratios of the Lengths of the Bodies,  $Z. z :: L \times L^{\frac{1}{4}}. 1 \times 1^{\frac{1}{4}}.$

*Cor. 4.* If this *Proposition* be true, and if the moving Forces of corresponding secreting Pipes be as the Capacities of the Pipes, or as the Capacities of corresponding Blood-Vessels ; the Sums of the Quantities discharged by all the corresponding Glands, or any given Number of them, in a given Time, will be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels : For, since the Discharges of any two corresponding Glands are in these Ratios ; the Sum of the Discharges of all the Glands, or of  
any



any given Number of corresponding Glands, will be in the same Ratios. If  $S, s$  denote those Sums, then  $S. s :: D^2 \sqrt{D}. d^2 \sqrt{d}$ . And if  $S, s, D, d$  denote the mean Sums of the Discharges in a given Time and mean Diameters of corresponding Blood-Vessels of Bodies of different Lengths, each Mean being taken from a considerable Number of Bodies of the same Length; then, since the mean Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies,  $S. s :: L \times L^{\frac{1}{4}}. l \times l^{\frac{1}{4}}$ .



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*Of the Discharges of Human Bodies.*

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## Proposition XXXII.

**T**HE Mean Quantities of Food and Discharges in a natural Day, taken from all the Food and Discharges of a Month, are nearly equal in healthful Bodies.

For I have found by statical Experiments, that tho' the Food and Discharges of healthful Bodies be rarely equal in single Days; yet the mean Quantities in a natural Day, taken from all the Food and Discharges of a Month, are always nearly equal. And therefore, the *Proposition* is true.

Here it may be proper to take notice of three Things, which by  
Some

Some may be thought Objections against this *Proposition*.

The *first* is the Difference which has been found in the Weight of a grown healthful Body at different Seasons of the Year. *Sanctorius* says, that temperate Bodies are three Pounds heavier in Winter than they are in Summer, and that the Augmentation and Diminution of Weight are made in Autumn and the Beginning of Summer. And in this Climate I have found, that healthful Bodies are heavier in Winter than in Summer, and that they grow heavier in Autumn, and lighter again in the Spring; but for want of a sufficient Number of Experiments, I have not been able to determine, how much grown healthful Bodies taken one with another are heavier in Winter than they are in Summer. They cannot be much heavier; for I have observed, and the same obtains



tains in *Italy*, that any considerable Increase of Weight made in a small Compass of Time, is very apt to cause Diseases. If we suppose Bodies to be four *Averdupois* Pounds heavier, and that they gain this Weight in Autumn and lose it in the Spring, in the Space of two Months; then the Food will exceed the Discharges in Autumn and fall short of them in the Spring, by an Ounce in a Day taking one Day with another: But an Ounce is so small a Difference between the Food and Discharges in a natural Day, that they may be truly said to be nearly equal in a grown healthful Body at all Seasons of the Year.

The *second* is the Change which is continually made in the Weight of a growing Body; but if we consider the Quantity and Time of its Growth, we shall find its Food and Discharges in a natural Day to be  
very

very nearly equal. For if a Child when it is born weigh 12 Pounds, and in twenty Years (which I shall suppose to be the Time of growing) come to weigh 168 Pounds; the Food will exceed the Discharges in a natural Day, taking one Day of the whole Time of its Growth with another, by something more than the third part of an Ounce. 'Tis true a healthful Child from its feeding plentifully, sleeping much, and wanting Exercise, grows much more the first half Year than it does afterwards in the same Compass of Time; and yet even then there is but little Difference between the Food and Discharges in a natural Day, taking one Day with another. For if its Weight when it is born be doubled in the first half Year, the Food will exceed the Discharges by little more than an Ounce in a Day, taking one Day with another. Therefore the  
Food

Food and Discharges in a natural Day may be truly said to be nearly equal in a healthful Body.

The *third* is the great Change which we frequently see made in the Weights of grown Bodies in the Compass of a few Years; and yet if we consider the Quantity of the Change, and the Time in which it is made; we shall find little Difference between the Food and Discharges in a natural Day, taking one Day of that Time with another. For if a grown Body gain in Weight 50 Pounds in five Years Time, the Food will not exceed the Discharges by half an Ounce in a natural Day, taking one Day of that whole Time with another.

*Cor. 1.* If  $N, n$  denote the mean Quantities of Food in a natural Day of two healthful Bodies, taken from their whole Quantities of Food in a Month;



Month; and P, U, S, p, u, s the mean Quantities of their Perspiration, Urine, and Stool, taken from the whole Quantities of those Discharges in a Month; then by this *Proposition*,  $N = P + U + S$ , and  $n = p + u + s$ .

*Cor. 2.* If a healthful Body at all Seasons of the Year take daily the same Quantity of Food in every Month, taking one Day of the Month with another; the daily Sum of the Discharges in every Month, taking one Day of the Month with another, will be likewise nearly the same at all Seasons of the Year. And therefore, if either Perspiration, Urine, or Stool be greater in some Months of the Year than in others; the Sum of the other two will be as much less: Otherwise the Sum of the three could not be given.

The Truth of these two *Corollaries* will appear from the following Table.

K k

Months

Months.	Morning.			Afternoon.			Night.		Stool.	Total Urine.	Total Perpiration.	Total Discharges.	Total Food.
	Breakfast.	Dinner.	Supper.	Urine.	Perpiration.	Urine.	Urine.	Perpiration.					
April.	$23\frac{11}{30}$	$43\frac{29}{30}$	$16\frac{13}{60}$	$8\frac{23}{60}$	$11$	$17\frac{77}{180}$	$16\frac{1}{12}$	$15\frac{97}{180}$	$5\frac{16}{60}$	$41\frac{8}{9}$	$37\frac{5}{8}$	$84\frac{12}{60}$	$83\frac{31}{60}$
May.	$23\frac{9}{10}$	$41\frac{21}{60}$	$28\frac{19}{30}$	$7\frac{11}{60}$	$13\frac{7}{60}$	$17\frac{22}{60}$	$16\frac{5}{12}$	$19\frac{11}{60}$	$7\frac{5}{12}$	$40\frac{29}{30}$	$44\frac{73}{120}$	$93\frac{1}{3}$	$92\frac{16}{60}$
June.	$27\frac{1}{5}$	$48\frac{2}{15}$	$15\frac{1}{10}$	$7\frac{2}{15}$	$15\frac{41}{60}$	$12\frac{1}{10}$	$13\frac{26}{30}$	$22\frac{23}{30}$	$5\frac{21}{60}$	$33\frac{23}{30}$	$51\frac{3}{20}$	$90\frac{7}{30}$	$90\frac{13}{30}$
July.	$25\frac{59}{60}$	$41\frac{7}{60}$	$15\frac{32}{60}$	$7\frac{47}{60}$	$14\frac{5}{60}$	$10\frac{3}{10}$	$12\frac{3}{10}$	$19\frac{19}{60}$	$5\frac{51}{60}$	$30\frac{23}{30}$	$46\frac{26}{60}$	$82\frac{2}{3}$	$82\frac{38}{60}$
August.	$22\frac{1}{6}$	$42\frac{7}{20}$	$21\frac{1}{12}$	$9\frac{2}{28}$	$17\frac{1}{13}$	$10$	$12\frac{9}{28}$	$20\frac{9}{13}$	$4\frac{21}{72}$	$29\frac{3}{4}$	$52$	$86$	$85\frac{86}{90}$
Septem <sup>r</sup> .	$18\frac{43}{60}$	$48$	$19\frac{3}{4}$	$7\frac{1}{2}$	$13\frac{29}{60}$	$13\frac{7}{60}$	$15\frac{1}{2}$	$19\frac{14}{15}$	$5\frac{9}{60}$	$36\frac{7}{60}$	$44\frac{1}{2}$	$85\frac{23}{30}$	$85\frac{4}{5}$
October.	$18\frac{51}{60}$	$45\frac{53}{60}$	$15\frac{21}{60}$	$7\frac{1}{5}$	$9\frac{59}{60}$	$13\frac{41}{60}$	$16\frac{39}{60}$	$17\frac{31}{60}$	$4\frac{23}{60}$	$37\frac{7}{12}$	$37\frac{7}{12}$	$79\frac{9}{12}$	$80\frac{5}{12}$
Novem <sup>r</sup> .	$21\frac{8}{13}$	$40\frac{12}{13}$	$15\frac{3}{52}$	$7\frac{17}{26}$	$8\frac{49}{52}$	$12\frac{39}{52}$	$16\frac{9}{13}$	$18\frac{1}{52}$	$4\frac{37}{52}$	$37\frac{5}{32}$	$35\frac{17}{32}$	$77\frac{6}{13}$	$77\frac{31}{52}$

This

This Table was made from a Course of Statical Experiments. The natural Day is divided into three Parts, Morning, Afternoon, and Night; the Morning contains six Hours from eight to two, the Afternoon six Hours from two to eight, and the Night the remaining twelve Hours. I observed the Food and the Discharges in these three Parts of the Day, every Day for eight Months together; and with the Means taken from all the Food and all the Discharges in the several Months, I composed the Table: From which it appears,

*First*, That Perspiration and Urine vary in their Quantities at different Seasons of the Year, and that as one encreases the other lessens. In *April* and *May* they were nearly equal, only Urine exceeded Perspiration a little in *April*, and was exceeded by it a little in *May*. In



the three Summer Months, *June*, *July*, and *August*, taken one with another, Perspiration exceeded Urine in the Proportion of about 5 to 3. In *October* and *November* they were nearly equal again, only Urine exceeded Perspiration a little in *November*. At the End of this Month I was interrupted, and hindered from carrying on the Experiments throughout the whole Year, as I at first intended; but I repeated them for about ten Days in cold frosty Weather, and found that Urine then exceeded Perspiration as much as Perspiration exceeded Urine in Summer.

*Secondly*, That Stool is but a small Discharge when compared with Perspiration and Urine, and is but little influenced by the Seasons of the Year in healthful Bodies. It was a little larger in *May* than in the other Months, from a gentle *Diar-*  
*rhæa*,

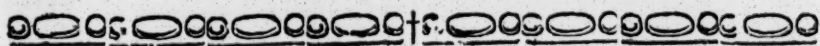
*rhæa*, for about twenty Days in that Month. And it was a little less in *October* and *November*, from the Quantity of Food being less in those Months than in the others.

*Thirdly*, That the daily Food and daily Discharges taken from all the Food and all the Discharges of a Month, are nearly equal at all Seasons of the Year in healthful Bodies, only the Discharges fall a little short of the Food in Autumn, and exceed it a little in the Spring. The Difference between the Food and Discharges at these Seasons arises, from Perspiration being more diminished in Autumn by the Cold of the external Air, than Urine is increased; and more increased in the Spring by the Warmth of the Air, than Urine is diminished. Urine takes up some Time at these Seasons to have its Increase and Diminution made equal to the Diminution and Increase of Perspi-

Perpiration. And hence it is that Bodies grow heavier in Autumn and lighter in the Spring; and by Consequence, that they are a little heavier in Winter than they are in Summer. The Change of Weight in Spring and Autumn is not great in healthful Bodies, and probably does not exceed above three or four Pounds; for I have known an Increase of five or six Pounds to have caused a Disease in the latter End of Autumn: But an Increase of four Pounds in two Months is at the Rate only of about an Ounce in a Day: And the same Increase in three Months is at the Rate only of about two third Parts of an Ounce in a Day, taking one Day with another.

Pro-





## Proposition XXXIII.

*S*Upposing the same Things as are supposed in the 31st Proposition and its 3d Corollary; and that the Quantities discharged by Stool in a natural Day, taken from the whole Quantities of that Discharge in a Month, are in the same Proportion as the daily Discharges of other corresponding Glands taken from their whole Discharges in a Month; the Sum of the Discharges by Perspiration, Urine, and Stool in a natural Day, taken from their whole Quantities in a Month, will in healthful Bodies of different Lengths be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels, that is,  $P+U+S. p+u+s::D^2\sqrt{D}.d^2\sqrt{d}.$

For

For the Sums of Perspiration and Urine in a natural Day, taken from their whole Quantities discharged in a Month, are in that Proportion by the 4<sup>th</sup> Corollary of the 31<sup>st</sup> Proposition: And the Quantities discharged by Stool in a natural Day, taken from the whole Quantities of that Discharge in a Month, are by Supposition as the daily Discharges of other corresponding Glands taken from their whole Discharges in a Month: And therefore, the Sums of the three Discharges in a natural Day, taken from the wholes of their respective Quantities in a Month, will be in the same Proportion, that is,  $P+U+S. p+u+s :: D^2 \vee D. d^2 \vee d.$

*Cor. 1.* If the Diameters of corresponding Blood-Vessels be in the subduplicate Ratios of the Lengths of the Bodies; the Sums of the Quantities of Perspiration, Urine, and Stool

Stool discharged daily by healthful Bodies of different Lengths, when each Quantity is taken from the whole of that Discharge for a Month, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies. If  $D. d::\sqrt{L}.\sqrt{l}$ , then will  $P+U+S. p+u+s:: L \times L^{\frac{1}{4}}. l \times l^{\frac{1}{4}}$ .

If this *Proposition* obtain in healthful Bodies; then will this *Corollary* obtain, when the Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies. They are in this Proportion in perfectly regular and well-proportioned Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; and the mean Diameters of corresponding Blood-Vessels of all healthful Bodies of different

L l

ferent



ferent Lengths, when each Mean is taken from the Diameters of those Vessels in a considerable Number of Bodies of each Length, are likewise in the same Proportion: And therefore, if this *Proposition* be true, the mean Sums of the Quantities of the Discharges in a natural Day of healthful Bodies of different Lengths, when the Quantity of each Discharge is taken from its whole Quantity in a Month, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies: But those Sums of the Discharges are equal to the mean Quantities of Food in a natural Day, taken from the whole Quantities of Food in a Month, by *Cor. 1. Prop. 32*: And by Consequence, the mean Quantities of Food in a natural Day of healthful Bodies of two different Lengths, will be in Ratios compounded of the simple  
ple

ple and subquadruplicate Ratios of these Lengths. This Proportion obtains nearly in the *Royal and Blew-Boys Hospital*. For upon inquiring into their Food I found, that taking one Day of the Week, and consequently one Day of the Month, with another, the Quantities of Food taken daily by Bodies whose Lengths are 69 and 54 Inches, are 109 and  $85\frac{1}{2}$  *Averdupois* Ounces: But these Quantities of Food are nearly in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies; only the Food of the Boys compared with that of the Men, is greater than in this Proportion by about  $5\frac{1}{2}$  Ounces in a Day; which may be owing to the Food of the Boys being something more liquid than the Food of the Men, and to their using more Exercise. In the Food of the Boys, the liquid part is to the solid part a

L 1 2

little

little more than 3 to 1; and in that of the Men, a little more than  $2\frac{1}{2}$  to 1.

Lengths of the Bodies in Inches.	The Lengths into the biquadrate Roots of the Lengths.	Whole Quantities of Food or Discharges in a natural Day in <i>Averdup.</i> Ounces.
72	2097	116
69	1988	109
66	1881	103
60	1670	$91\frac{1}{2}$
54	1463	80
48	1263	69
42	1069	$58\frac{1}{2}$
36	882	48
30	702	38
24	531	29
18	371	20

This Table in its third Column contains the mean Quantities of Food, or mean Quantities of the Discharges,



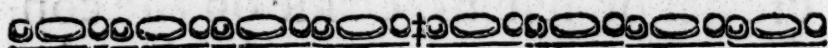
Discharges, in a natural Day, of healthful Bodies of the Lengths set down in the first Column. I computed it by the second Column, which contains the Products of the Lengths and biquadrate Roots of the Lengths of the Bodies, taking 109 *Averdupois* Ounces as a proper Quantity of Food for well-proportioned Bodies 69 Inches in Height, on Supposition that the liquid part of the Food to the solid is in the Proportion above-mentioned. The Food of very young Children, as being wholly liquid, should be more than is assigned them by this Table; but what the exact Quantity is I know not for want of Experiments.

*Cor. 2.* If this *Proposition* be true, as it appears to be by the last *Corollary*; the Sums of the Discharges by Perspiration, Urine, and Stool,  
in

in a natural Day, taken from their whole Quantities in a Month, will in Bodies of equal Lengths be in Ratios compounded of the simple and subquadruplicate Ratios of their Quantities of Blood. For the Squares of the Diameters of corresponding Blood-Vessels are as the Quantities of Blood in Bodies of equal Lengths, that is,  $D^2. d^2 :: Q. q$ ; and the Square-Roots of the same Diameters, are as the biquadrate Roots of the Quantities, that is,  $\sqrt{D}. \sqrt{d} :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$ : And therefore,  $P + U + S. p + u + s :: Q \times Q^{\frac{1}{4}}. q \times q^{\frac{1}{4}}$ .

For Instance, if the Quantities of Blood in two healthful Bodies of the same Length be as 3 to 2, then  $P + U + S. p + u + s :: 39480. 23784$ . If the Length of the Bodies be six Feet, and the Quantity of Food in a Day of that Body which has the greater

greater Quantity of Blood be 116 Ounces; the Quantity of Food in a Day of the other Body will be about 70 Ounces.



Proposition XXXIV. Problem V.

**T**O determine the Proportion which Perspiration bears to Urine at different Seasons of the Year, at different Times of the natural Day, under different Kinds and Degrees of Exercise, in Bodies of different Ages, and Bodies which are nourished by different Kinds of Food.

I. Perspiration with respect to Urine is greater in Summer than in Winter. It was near three times as great in the Body from which the Table in p. 258 was made, and it is generally greater, tho' not in  
the



the same Proportion, in healthful Bodies. A warm Air warms the Skin and increases Perspiration, and a cold Air cools the Skin and lessens Perspiration ; but as Perspiration increases or lessens, Urine on the contrary lessens or increases by that Table. The Proportion of Perspiration to Urine is regulated by the Heat of the Skin ; and as far as the Heat of the Skin is increased or lessened by the Heat or Cold of the external Air, the Proportion of Perspiration to Urine will be increased or lessened by the Heat or Cold of the external Air. Accordingly, I have observ'd Perspiration to have been only equal to, nay sometimes to have fallen short of, Urine in the Summer-Time, in Bodies which have been little exposed to the Heat and Cold of the external Air. And as far as I can judge from the Observations I have made,  
this

this chiefly happens in Bodies whose Skins are naturally cool by a spare Diet, or a languid Motion of the Blood, or both.

II. From the Table *p.* 258 it appears, that both Perspiration and Urine are greater in the Afternoon than in the Morning, in the Day than in the Night. But as the Man from whom that Table was made, walked some Hours every Day, and generally more in the Morning than in the Afternoon; we cannot from that Table determine these Discharges, and consequently their Proportions to one another at different Times of the Day in Bodies which are at Rest. That I might be satisfied of this, I took the Quantities of Perspiration and Urine discharged by two healthful Men B and D, in the several Hours of the Day for four Days together in very hot  
M m                      Weather,

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 Weather, and with the mean Quan-  
 tities of the Discharges in those  
 Hours, composed the following Ta-  
 ble.

Hours.	B		D	
	Perspi- ration.	Urine.	Perspi- ration.	Urine.
6	$1\frac{7}{8}$	$0\frac{15}{16}$	2	I
7	$1\frac{5}{8}$	I	$1\frac{2}{5}$	I
8	2	I	$1\frac{1}{2}$	$1\frac{1}{5}$
9	2	$1\frac{1}{8}$	$1\frac{4}{5}$	$1\frac{3}{10}$
10	2	$1\frac{1}{5}$	$1\frac{9}{10}$	I
11	$1\frac{3}{4}$	I	$1\frac{2}{5}$	I
12	$2\frac{1}{3}$	I	$1\frac{4}{5}$	I
1	$2\frac{1}{3}$	$1\frac{1}{4}$	$1\frac{1}{2}$	I
2	2	I	$1\frac{1}{2}$	I
3	$3\frac{1}{2}$	$1\frac{1}{2}$	2	I
4	$2\frac{1}{3}$	2	$1\frac{1}{2}$	$1\frac{1}{7}$
5	$2\frac{1}{3}$	2	$1\frac{4}{5}$	I
6	$2\frac{2}{3}$	2	2	I
7	2	2	2	I
8	$2\frac{1}{3}$	$2\frac{1}{3}$	2	I
9	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$
10	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$

B took 86 Ounces of Food in a Day,  
 and D only 63 : They both eat their  
 Breakfast



Breakfast at eight a Clock in the Morning, dined at two, and supped at eight at Night. It is to be observed, that the Numbers corresponding to the Hour 6 in the Morning, are the mean Quantities of Perspiration and Urine which were drawn off from the Blood in every Hour of the Night, taking one Hour with another.

Setting aside Exercise, and supposing the natural Day to be divided into three equal Parts, Morning, Afternoon, and Night, and the Morning to begin at six a Clock; the Quantities perspired by B and D in the Morning, Afternoon, and Night, were nearly by this Table, 16, 20, 15, and 13, 14, 16; and the Quantities of Urine made by these Bodies in the same Times, were nearly 9, 15,  $7\frac{1}{2}$ , and 8,  $8\frac{1}{2}$ , 9. The Proportions of Perspiration to Urine in these Times, were 177, 133, 200, in B;  
M m 2 and

and 162, 164, 177, in D. Hence we learn, that the Proportion of Perspiration to Urine is greater in the Night when Bodies are at Rest, than it is in the Day-time ; that there is no great Difference in this Proportion in these Times, in Bodies which eat sparingly and drink but little Wine, which was the Case of D ; and that in Bodies which eat plentifully and drink Wine, this Proportion is often less in the Afternoon than it is in the Morning, which was the Case of B. Wine in most Bodies increases the Discharge by Urine ; and as that Discharge increases, the Proportion of Perspiration to it will necessarily lessen ; unless Perspiration be increased in the same Proportion as Urine is increased, which I believe very seldom, if ever, happens. Hence we may judge of the Proportion of Perspiration to Urine at different Times  
of

of the natural Day, in Bodies which are at Rest; and at the same time see, that notwithstanding the Inequalities of this Proportion in different Parts of the natural Day, the Proportion of Perspiration to Urine in the whole natural Day, is nearly the same at the same Season of the Year in healthful Bodies; it was nearly 162 in B, and 168 in D.

III. The Proportion of Perspiration to Urine, is increased by all those Exercises which increase the Motion of the Blood and warm the Skin. Two Men of nearly the same Height and Weight walked a Mile in half an Hour, and in that Time each perspired about  $3\frac{1}{2}$  Ounces, which is about three times as much as they ordinarily perspire in the same Time in the Heat of Summer without Exercise. This Degree of Exercise gave a glowing Warmth  
to



to the Skin, but did not make them sweat, but would have caused a gentle breathing Sweat, had it been continued much longer. The same Men walked above two Miles in half an Hour, and in that Time one perspired nine Ounces, and the other eight, which was about eight times as much as they ordinarily perspire in the same Time in the Heat of Summer without Exercise. This Degree of Exercise made them sweat profusely. A third Man, who was fat and much taller than either of the others, walked two Miles in half an Hour, and in that Time perspired thirteen Ounces and a half, which was about nine times as much as his Summer's Perspiration in the same Time without Exercise. And a Boy seven Years old, who without Exercise perspired half an Ounce in half an Hour in the Heat of Summer, by walking at  
such

such a Rate as gave a gentle Warmth to his Skin, but did not make him sweat, perspired about three times as much in the same Time. At the Beginning of the Exercise of Walking I have observed, that Urine has been increased as well as Perspiration; but on continuing the Exercise, Urine in a very little Time has decreased again, and grown less than it was before the Exercise, by the large Discharge which was made by the Skin. If we suppose the Quantity of Urine not to be lessened by Exercise, as it may not in Persons who by Drink supply the Loss which is made by Perspiration, then will the Proportion of Perspiration to Urine be 6 to 1, in Persons who walk at such a Rate as to give a glowing Warmth to their Skins, but not to cause Sweat, and 16 to 1 in Persons who walk at such a Rate as to sweat profusely, on  
Sup-

Supposition that the Proportion of Perspiration to Urine is 2 to 1 in the Heat of Summer. The Exercise of Riding increases Perspiration, but neither so suddenly, nor in so great a Degree, as the Exercise of Walking, as appears from the following Instance. A healthful Man upwards of ninety Years of Age, who commonly without Exercise discharged four or five times as much by Urine as he did by Perspiration, observed that in the Night, after riding several Hours the Day before, he always perspired as much as he discharged by Urine. In this Case therefore, Perspiration to Urine was increased by Riding in the Proportion of 4 or 5 to 1.

IV. The Proportion of Perspiration to Urine in Bodies of different Ages will be greater or less, as the external Heat of the Body is greater



greater or less : But the external Heat of the Body is less in old Bodies than it is in others : And therefore, the Proportion of Perspiration to Urine will be less in old Bodies than it is in others. In the old Man above-mentioned, this Proportion was less than in Bodies in the Vigour of their Age in the Heat of Summer, in the Proportion of 1 to 8 or 10.

V. The Proportion of Perspiration to Urine in Bodies nourished by different Kinds of Meats and Drinks will be greater or less, as those Meats and Drinks are fitted to warm or cool the Skin by warming or cooling the Blood, and increasing or lessening its Motion. As to Drinks, Water and watry Liquors drunk hot warm the Skin and increase Perspiration; and drunk cold they cool the Skin, and increase U-

N n

rine.

rine. Three or four Quarts of Chalybeate Waters will pass off by Urine in many Bodies in less than three Hours Time. Wine and other fermented Liquors drunk cold and in large Quantities frequently pass off very quick by Urine, but not altogether so quick as cold Water; and drunk hot they increase Perspiration. Water impregnated with Nitre is colder and more diuretick than plain Water. As to Meats, those which are dry and warming increase Perspiration; and those which are moist and cooling increase Urine. Ripe Apples increase Perspiration, as appears from the following Instance. The old Man above-mentioned, whose Perspiration in the eighty-sixth Year of his Age, was not above  $\frac{1}{4}$ th part of his Urine, by eating three Quarters of a Pound of mellow Apples at Night with Bread, brought his Perspiration  
on

on to be nearly equal to his Urine, less only in the Proportion of 13 to 16. That this Change in Perspiration was owing to the Apples, appeared from hence, that on his leaving them off, his Perspiration grew less, and returned to what it was before he began to eat them.

From these Instances it appears, that the Proportion of Perspiration to Urine is increased or lessened by Meats and Drinks, as they increase or lessen the Heat and Motion of the Blood.

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F I N I S.

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## ERRATA.

Page 4. Line 2, 3. *for*, as often as there are physical Points, *read*, for every physical Point. p. 8. l. 6. f. *if*, *r.* and. p. 10. l. 20. f. the Place, *r.* the Hole or Place. p. 14. l. 8. f. By, *r.* From. p. 17. l. 18. f. 12 to 17, *r.* 17 to 12. p. 35. l. 16. f.  $H+S$ . *r.*  $\frac{H+S}{L}$ . p. 38. l. 4, 5, 6. *dele* and the Capacities of the two Pipes are as the Capacities of the two Systems. p. 46. l. 12. f. the subduplicate, *r.* the inverse subduplicate. p. 48. l. 12. f.  $17\frac{1}{2}$ , *r.*  $17\frac{1}{8}$ . l. 19. f.  $206\frac{5}{8}$ , *r.*  $106\frac{5}{8}$ . p. 51. l. 13, 14, 15. *dele* and the Capacities of two corresponding Pipes, as the whole Capacities of the two Systems. p. 79. f.  $3\frac{1}{2}$ , *r.*  $3\frac{1}{3}$ . p. 93. l. 5, 6. f. Tremor, *r.* Tremors. p. 145. l. 7. f. Heart, *r.* Hearts. p. 183. l. 12. *after* Wind, *add*, A the Degree of Heat in the Wind. p. 184. l. 23. f. be different, *r.* be given. p. 227. l. 13. f. Mo-on, *r.* Motion. p. 119. f. Cor. 4. *r.* Cor. 3. p. 132. l. *ult.* f. Prop. 12. *r.* Prop. 13.

